Macroeconomic News and LOB in Foreign Exchange ECN Market

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Msc in Management Program

Submitted in partial fulfillment
of the requirement for the degree of

Master of Science in Management (Finance)

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© May, 2015

Abstract

We investigate the macroeconomic news effect on the dynamics of the limit order books (LOB) for euro-dollar ECN market in different economic states between Jan. 2006 to Dec. 2009. Using a VAR-STR model on the news surprise, pure news, aggregated good and bad news, we show that news effects on the LOB dynamics vary in different states of economy. The LOB dynamics are measured by depth, spread, slope and volatility. In contract to slope and volatility, depth and spread strongly respond to news surprise and pure news during recession and expansion. These characteristics are more affected by aggregated good and bad news during expansion. News effects are robust to alternative characteristic measures, the different sides of the LOB and the different levels in the LOB.

Key words: *limit order book, depth, spread, slope, macroeconomic news*

Acknowledgements

Foremost, I would like to express my deepest gratitude, special appreciation and thanks to my supervisor Dr. Walid Ben Omrane. Without his encouragement, patience, and excellent guidance, I would never have been able to finish my thesis. Also, I feel extremely lucky to have a supervisor who cared so much about my work, and who responded to my questions and queries so promptly.

I would also like to express my appreciation to my committee member Dr. Robert Welch, who provided great advices regarding academic writing. During my supervisor's absence, I retained enthusiasm about my work with his timely support and encouragement.

A very special thanks goes out to Dr. Ernest Biktimirov for the support to make this thesis possible. Also as my field advisor at the beginning of this program, Dr. Biktimirov provided me with many useful advice regarding career path.

Lastly, I acknowledge my gratitude to my beloved family and friends. Great thanks to my best friend Jiahui Wang who always listen to me. I was continually amazed and inspired by her perseverance and determination. Special thanks to Xinyao Zhou for helpful advices. I would like to thank for the friendship provided by the other colleagues of MSc program. And I would like to thank our administration officers Carrie Kelly, Victoria Steel and Valerie Desimone.

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1. Introduction

The effect of macroeconomic news on the dynamics of the limit order books (LOB) has been investigated in previous studies. Erenburg and Lasser (2009) show the release of the macro news affects the depth and spread of the LOB. They find that macroeconomic announcements lead to deterioration in the quality of LOB. Andersen et al. (2003) demonstrate that macro news announcements have a lasting effect on exchange rate volatility.

The recent U.S. crisis in 2008 caused large fluctuations in LOB liquidity and volatility in FX ECN market (Mancini et al., 2012). Laakkonen and Lanne (2010) verify that news effects depend on economic states, and they find that bad news has a stronger effect on exchange rate volatility during an economic expansion. Ben Omrane and Savaser (2013) document that the impact of news varies over business cycles. They show that nearly one third of the most important macro news has sign-switching effects during the recent global crisis. Most previous studies that examine news effects in different business phases, such as recession and expansion, focus on the return or volatility of foreign exchange.

Instead of using the National Bureau of Economic Research (NBER) dates, Laakkonen and Lanne (2010) use the Smooth Transition Regression (STR) model (Teräsvirta, 1994) to measure business cycles. STR is a more accurate and detailed method to identify the states of economy continuously by using Institute for Supply Management Survey index (ISM) as a business regime indicator.

Characteristics of the LOB describe liquidity and volatility. Previous studies point out that limit orders play an important role in understanding the market structure of the electronic trading systems. Usually, these studies use characteristics based on the limited portions of LOB. Ahn et al. (2001) analyze the role of limit orders in the liquidity provision in the stock market. They use depth and price volatility to illustrate the dynamics between the order book state and order flow for the ask and bid sides. However, recent studies verify the presence of information beyond the best quote level in LOB. Cao et al. (2004) argue that the quotes beyond the best bid and ask of the LOB contain important information.

Since previous literature focuses primarily on the news effects on asset return or volatility during business cycles, with only limited information from the LOB, such as the best quotes, we contribute by examining the response of four LOB characteristics to macroeconomic news during different business cycles by using all LOB levels. We investigate the effect of macroeconomic news on LOB dynamics by using characteristics which can fully describe the shape of LOB. Besides volatility, we choose spread, depth and slope to describe the liquidity of LOB. Coppejans et al. (2001) and Naes and Skjeltorp (2006) find that these three characteristics are correlated, while describe different LOB aspects.

Our data is the euro-dollar exchange rate and 89 news categories from the US and Euro zone countries from Jan. 3rd 2006 to Dec. 1st 2009. To avoid noise present in tick-by-tick data, we use 5 minutes intervals in our sample (Gunther, W. 2008). We

construct a vector auto regression (VAR) model to investigate the dynamics among characteristics by using information from all price levels in the LOB. Furthermore, we apply a STR on VAR to examine the response of characteristics to the macroeconomic news in different business regimes.

Our results show that macro news has effects on LOB characteristics and the news effects vary with the states of the economy (recession or expansion) and the background of the crisis. Depth is more affected by the news surprise and pure news during the expansion. Quoted spread and volatility are more affected by news surprise during the expansion but have a stronger response to pure news during the recession. Slope is more affected by the news surprise and pure news during the recession. For good and bad news, depth, quoted spread and volatility (but not slope) show significantly stronger response during the expansion. We find that the news related to housing market and news viewed as a business indicator are consistently significant in the recession or expansion for all four characteristics.

In summary, our study contributes to the existing literature in several ways. First, we empirically show that macro news significantly affects LOB characteristics. Using a VAR-STR model, our study shows that the LOB response of macro news varies with different states of economy. Second, we use all LOB quote levels to construct the LOB characteristics and find that, by considering full information, LOB characteristics react more intensely to macro news, providing empirical evidence that the upper levels in LOB are informative. The remainder of the thesis is organized as

follows: Section 2 reviews the literature. Section 3 presents the methodology. Section 4 describes the data. The results are discussed in the Section 5. Robustness check is shown in the section 6. Section 7 concludes the findings.

2. Literature Review

Information reflected in LOB is currently of interest in a growing literature. Most previous studies about LOB information use only the best quotes or a limited portion of the LOB. Recent evidence indicates the presence of information beyond the best quote level.

Most empirical studies find that LOB information is reflected in certain characteristics of the book. Biais et al. (1995) use up to five best quotes of LOB in the Paris Bourse to study the LOB liquidity by using spread and slope to measure supply and demand. They conclude that this information is useful when predicting the liquidity of stock market. A growing body of literature discusses the relation between public announcements and these LOB characteristics. Macroeconomic news affect the exchange price directly or affect it indirectly by influencing the order flow in the LOB. Nearly one-third of the news response contribute to the volatility of exchange rates (Evans and Lyons, 2008; Love and Payne, 2008).

The range of the news has been expanded to describe different kinds of news effects. Riordan et al. (2013) study the effect of news on trading intensity, liquidity, and volatility of stocks traded on the Toronto Stock Exchange (TSE). They categorize

news as “positive”, “negative” and “neutral” and find that the adverse selection costs around the arrival of negative messages is higher than that of positive or neutral messages. Bauwen, Ben Omrane and Giot (2005) categorize nine kinds of scheduled and unscheduled news in the euro/dollar market. They address the influence of scheduled and unscheduled news announcements in three phases: pre-announcement periods, contemporaneous and post-announcement periods. They find that volatility increases just before scheduled news releases.

Other characteristics are influenced by the macro news. Erenburg and Lasser (2009) document the influence of spread, depth and volatility after scheduled macro news releases by using the LOB data of the Island ECN. They find that spread increases and depth decreases when the news occurs, which agrees with anecdotal evidence that traders prefer to submit more limit orders when volatility is high. In other words, traders tend to more be aggressive around news releases.

Another research area focuses on the effect of news on the LOB characteristics in different economic phases. Andersen et al. (2003) find the occurrence of news announcements triggers return variation. They show that bad news has greater influence compared to the good news, which indicates an asymmetry effect, and that bad news in “good times” have a larger impact compared to “bad times”. Laakkonen and Lanne (2010) study effect of macro news on the volatility of EUR/USD exchange rate over the states of the economy. By using the STR model with Institute for Supply Management Survey (ISM) as transition variables (Teräsvirta, 1994), they capture the

state-dependent effect of news on volatility. Moreover, they sort the macroeconomic news into two categories: good news and bad news. They find that bad news has a stronger effect on volatility then good news. Ben Omrane and Savaser (2013) document the effect of scheduled and unscheduled news on exchange rates from 2005 to 2009. They find the sign effect of some news will change in different business cycles and investigate the factors that contribute to this sign-switching effect.

Recent empirical work suggests that connections exist among various LOB characteristics, such as the interactions between the liquidity characteristics of spread, depth and slope. The inside spread (difference between minimum ask price and maximum bid price) is a key indicator of liquidity which increases if the spread decreases. A very narrow spread indicates a liquid market; and depth is associated with quoted and effective spreads, especially for heavily traded stocks (Bessembinder, 2002). Liquidity increases if depth increases. Larger depth indicates high degree of trading intensity. A deep market can be expected to absorb larger buy and sell orders. Depth by Riordan et al. (2013) is computed from three price levels in the LOB. Slope is another effective way to access the LOB's information and it measures liquidity intensity or the elasticity that responds to the change of demand and supply curves.

Generally, deep markets will have smaller bid-ask spreads because of the increased competition among market makers for order flow (Cao et al., 2004). Theoretically, Coppejans et al. (2001) develop a model of market trading and predict an inverse relationship between depth and volatility. Furthermore, as stressed by

Duong and Kalev (2008), Naes and Skjeltorp (2006), slope is negatively related to price volatility. Using a VAR model applied to a maximum of five quotes levels in limit orders, Beltran, Durre and Giot (2004) study the ex-ante and ex-post relationships between volatility and liquidity to discover that liquidity declines when volatility rises, causing larger trading costs.

Since our study is based on highly frequency tick by tick intraday time series, which is time stamped to million seconds, we should pay attention to the two issues. The first problem is related to the formation of the LOB in which successive orders are submitted at irregular times. One way to deal with irregular spaced data is to use every event time update and tick record; the other is to use a joint time interval (Bauwens and Giot, 2001). In the case of high frequency data most authors tend to use equally spaced data for their study.

The second problem is that intraday seasonality exists in high frequency time series. The evidence of intraday seasonality patterns of the return volatility is pervasive. Empirical studies by Engle and Russell, 1998 and Bauwens and Giot, 2001 address the problem of removing intraday seasonality. Several methods can be applied to control or remove the seasonality. Beltran, Durre and Giot (2004) remove the seasonality effect by using trading day dummies. Usually ARCH and GARCH models are used in the volatility of low-frequency time series. For high frequency data, the effectiveness of ARCH and GARCH models is controversial. Another method for controlling seasonality is the intraday average observation model (IAOM),

introduced by Ben Omrane and Bodt (2007) where a Flexible Fourier Form (FFF) model is used to eliminate the intraday seasonality pattern on volatility (Andersen and Bollerslev, 1998, Andersen et al., 2003, Laakkonen and Lanne, 2010).

Recent literature argues that the 2008 crisis has influenced the global economy from financial markets to fundamental industries. This recent global recession is considered the worst financial crisis since the Great Depression of the 1930s and its effect on FX market is documented in literature. Melvin and Taylor (2009) provide an overview of the important events of the recent global financial crisis and their implications for exchange rates and market dynamics after 2007. They use the Global Financial Stress Index (FSI) to measure the severity of the crisis.

A crisis leads to a significant decrease in liquidity. Fratzscher (2009) models the time-varying effect of US shocks on exchange rates. He finds that FX reserves, current account positions and financial exposure are important in explaining the response of exchange rates to the financial crisis. He also finds that negative US-specific macroeconomic shocks during the crisis have triggered a significant strengthening of the US dollar. Goldstein and Kavajecz (2004) focus on the liquidity provision at the New York Stock Exchange during the crisis. They show that liquidity is diluted on the day after the market crash as the order book exhibited large spreads and poor depth. Engle et al. (2012) analyze the liquidity and volatility in the U.S. treasury securities market around the U.S. crisis and the following "flight-to-safety" periods. They document that treasury market depth declines sharply

during the crisis, accompanied by increased price volatility. In addition, volatility and depth at the best quotes exhibit a negative relationship and this relation becomes more persistent during the crisis. They find that the treasury market during recovery has lower market depth, along with higher trading size and greater price uncertainty.

3. Methodology

In this section, we introduce the method used to compute LOB characteristics over 5-min mid quote returns from tick data. Then we introduce Vector Auto Regression Model (VAR) with macro news as an exogenous variable to analyze the response of characteristics to macro news. The two-regime STR model is then augmented to the VAR model to analyze the effect of macroeconomic news corresponding to different economic phases.

3.1 Interval Characteristics

Instead of using every update in the LOB (tick-by-tick data), an equally-spaced-interval is chosen as basic-unit of observation in our study. To illustrate this point, we compare the pros and cons of tick-by-tick data and the interval data. Following Gunther, W. (2008) and Andersen et al. (2007), we can reduce “noise” in the high frequency data while keeping the intraday seasonality of the data by using equally spaced intervals. However, lower frequency may not reflect the characteristics of high frequency data. But noise in tick-by-tick data may obscure any change in the LOB which affects estimation. The actual LOB updates as long as there is a price or

size change from the previous tick. Hence, most updates hardly change the LOB. But some information is lost with aggregation. Normally, a longer the time duration for an interval implies more information is lost, with a lower level of noise. We use 5-minute interval to keep intraday pattern of the characteristics and to follow the standard practice of previous reach.

In this section, we show how to construct as 5 minute interval characteristic from the tick characteristics. We compute a time-weighted average of all tick characteristics in that interval. The weight is the inverse of the duration between each tick to the end point of the corresponding 5 minute interval (Bauwens et al., 2005). To start with, we introduce the basic notation for a 5-min interval $n = 1,2, \dots, N$, where $N = 288$ the total number of intervals are in a sample day which is 24 hours, for trading day $t = 1,2, \dots, T$, where T is the total number of days in the sample period. Diagram 1 represents a typical tick in the LOB.

Following the method of Bauwens et al. (2005), we label the time duration between each LOB update and the interval endpoint as τ seconds. τ_i represents the time duration between i^{th} tick in an interval *n* and the end time of the interval *n*, where $i = 1,2, \dots, \gamma_n$ where γ_n is the total number of ticks in the interval *n*. So the time duration in an interval *n* is $\tau_1, \tau_2 \dots, \tau_{\gamma_n}$. For instance, as shown in Diagram 1, τ_1 is the time duration between the 1st tick in the interval *n*=2 and the end point of the interval at *n*=2. The end point time is by definition. Let $X_{t,n,i}$ be a representative for

one of the characteristics in the LOB[1]. And the characteristic for interval *n* on day *t* is defined as:

$$X_{t,n} = \frac{\sum_{i=1}^{\gamma n}[(\frac{1}{\tau_i})\times X_{t,n,i}]}{\sum_{i=1}^{\gamma n}(\frac{1}{\tau_i})}, \quad (1)$$

where $X_{t,n}$ is the time-weighted average of characteristics in interval *n* at trading day *t*. $X_{t,n,i}$ is the characteristics in tick *i*, interval *n* at trading day *t*. In section 3.2, characteristics of the LOB are defined based on tick-by-tick data and then the characteristics for an interval *n* are calculated with equation (1).

In this case, the third tick which is updated nearest to the end of the 5-min interval has the largest weight. Because the weight is the inverse of the time duration between each tick updates to the end of its corresponding 5 minute interval. Since the time duration of the update which is closest to the end of the interval is the shortest, the tick that is nearest to the end of the interval has the largest weight.

In Appendix D, Diagram 1 shows an example of updates in the LOB. From the diagram, the first interval has three ticks, $i = 1, 2, 3$. τ_3 is the time duration of the tick *i*=3 which is nearest to the end of the second interval on day *t*. According to the equation above, the characteristics at tick *i*=3 have largest weight in forming that interval's characteristics.

[1] X_{n,τ_i} are the depth, the quoted spread and the slope and mid-price which is used to define the volatility of the LOB.

3.2 Characteristics of Limit Order Book

We measure the LOB information in two ways: liquidity and volatility. There are three different measures of liquidity: the quoted spread, the depth, and the slope. Spread reflects the magnitude of transaction cost and it measures how far the best ask price is from the best bid price. Depth measures the amount of liquidity in the LOB. And the slope measures the elasticity of the demand curve and supply curve of LOB. The last characteristic is volatility which measures the fluctuation and transition cost of LOB.

3.2.1 *The Depth*

The most cited depth method is simply the number of quoted forex units of each corresponding price level. However, to make full use of the information in the LOB, we follow Riordan et al. (2013) to compute the LOB depth. The robustness check for alternative depth methods of depth is in section 6.

According to Diagram 1 in Appendix D, denote the price level at tick i as $l = 1,2,3 \dots, L$, where L is the total number of the price levels in that tick i. The ask price at tick i with price level l in interval n is $P^A_{n,i,l}$ and the best ask price at each tick i is $P^A_{n,i,1}$. The bid price at each tick i with depth level l in interval n is $P^B_{n,i,l}$. E.g. the best ask price at each tick i is $P^B_{n,i,1}$. Assume the size on a certain price level at the ask side is $Q^A_{n,i,l}$, similarly the size on a certain price level at the bid side is $Q^B_{n,i,l}$. Thus the size at the best ask level is $Q^A_{n,i,1}$ and the size at the best bid level is $Q^B_{n,i,1}$, while the size at the second best ask level is $Q^A_{n,i,2}$. According to Ryan Riordan et al.

(2013), the depth for a tick is the sum of price-weighted sizes of all levels in that tick. Then the depth measure for every tick i at interval *n* is $Depth_{n,i}$:

$$Depth_{n,i} = \sum_{l=1}^{L}[Q_{n,i,l}^{A} \times P_{n,i,l}^{A}] + \sum_{l=1}^{L}[Q_{n,i,l}^{B} \times P_{n,i,l}^{B}], \quad (2)$$

where $Q_{n,i,l}^{A}$ is the size of level *l* at tick i in interval n at ask side; $Q_{n,i,l}^{B}$ is the size of level *l* at tick i in interval n at bid side. The depth at interval n in day t is:

$$Depth_{t,n} = \frac{\sum_{i=1}^{\gamma_n}[(\frac{1}{\tau_i}) \times Depth_{t,n,i}]}{\sum_{i=1}^{\gamma_n}(\frac{1}{\tau_i})} ,$$

where $Depth_{t,n}$ is the time-weighted average of depth at interval *n* in day *t*. From equation (2), depth by Riordan et al. (2013) is the sum of price-weighted size for both sides of the LOB. Depth is sum of the price-weighted size for every price level *l* in each tick *i*; in this case, depth is to measure the amount of liquidity in LOB. The depth by Riordan et al. (2013) is more informative than simply using the size to describe the amount of liquidity because the size here is weighted by the corresponding price at each level.

3.2.2 ***The Spread***

The quoted spread is a good indicator of the execution cost for a trade in case of small orders. Also, the spread is influenced by market impact. For example, the spread may be larger due to the size of the order (Riordan et al, 2013). In this case, we use the quoted spread to measure the spread of LOB.

For every tick *i* in interval *n*, the quoted spread measured in the basis points is:

$$QSpread_{n,i} = \left(\frac{P^{A}_{n,i,1} - P^{B}_{n,i,1}}{\frac{1}{2}\left(P^{A}_{n,i,1} + P^{B}_{n,i,1}\right)} \right) \times 10000. \quad (3)$$

Then the construct the interval quoted spread by using the method in section 3.1[2]. The quoted spread at interval n in day t is,

$$QSpread_{t,n} = \frac{\sum_{i=1}^{\gamma n} [(\frac{1}{\tau_i}) \times QSpread_{t,n,i}]}{\sum_{i=1}^{\gamma n} (\frac{1}{\tau_i})},$$

where $QSpread_{t,n}$ is the time-weighted average of quoted spread in interval *n* in day *t*. Quoted spread is different from the minimum spread which is the difference between the best ask price and the best bid price. From the equation (3), quoted spread is more informative and easier to interpret because it is defined as the percentage of the difference between best ask and bid quote to the mid-price, quoted spread is a percentage measure of trade execution cost in for the mid-price of every quote.

3.2.3 *The Slope*

Slope is a common information feature to measure the elasticity of the demand and supply curves. Naes and Skjeltorp (2006) and Duong and Kalev (2008) use daily data to measure the average slope across all price levels with LOB sizes considered. They calculate the average of bid and ask slope to get one slope measure for each tick by considering up to five price levels in a tick. They take the average across all the ticks to obtain one daily average slope.

[2] Multiply by 10,000 to enhance readability of the numbers multiplies the original quoted spread method. Scaling quoted spread by 1,000,00 does not change its statistical properties (Riordan et al., 2013)

The interval slope uses the same procedure as the previous characteristics. The slope at ask side for each i in an interval n is $Slope^{A}_{t,n,i}$. Then we compute the time-weighted average of the slope for ask side and get the interval slope at ask side: $Slope^{A}_{t,n}$. For the ask side, the slope for each tick i in an interval n is

$$Slope^{A}_{t,n,i} = \frac{1}{L}\left[\frac{q^{A}_{n,i,1}}{\frac{P^{A}_{n,i,1}}{m_{n,i}}-1} + \sum_{l=1}^{L-1}\left|\frac{\frac{q^{A}_{n,i,l+1}}{q^{A}_{n,i,l}}-1}{\frac{P^{A}_{n,i,l+1}}{P^{A}_{n,i,l}}-1}\right|\right], \quad (4)$$

with l=1, 2, ...L as the price level with in each tick *i*. $q^{A}_{n,i,l+1}$ is the natural logarithm ask size at tick level *l+1* and $q^{A}_{n,i,l}$ is the ask size at tick level *l*. $q^{A}_{n,i}$ is the natural logarithm of the sum of the size at all levels in a particular tick *i*. For instance, $q^{A}_{n,i,1} = \ln\left(Q^{A}_{n,i,1}\right)$. Denote mid-price as $m_{n,i} = \frac{1}{2}(P^{A}_{n,i,1} + P^{B}_{n,i,1})$ and denote $Q^{A}_{n,i,0} = 0$.

For the bid side, $q^{B}_{n,i,l+1}$ is the natural logarithm bid size at tick level *l+1* and $q^{B}_{n,i,l}$ is the bid size at tick level *l*. we take the absolute value of each term in the equation of the slope of the ask side and get $Slope^{B}_{t,n,i}$ with l=1, 2, ...L as the price level in each tick *i*. The reason we take the absolute value of the slope of the bid side is that best bid price is smaller than the mid-price, also we want to get the magnitude of the elasticity. Lastly, taking the simple average of the ask slope and bid slope to get the slope at interval n in day t at tick *i* is $Slope_{t,n,i} = \frac{Slope^{A}_{t,n,i} + Slope^{B}_{t,n,i}}{2}$.

The slope of the LOB at interval n in day t is,

$$Slope_{t,n} = \frac{\sum_{i=1}^{\gamma n}[(\frac{1}{\tau_i})\times Slope_{t,n,i}]}{\sum_{i=1}^{\gamma n}(\frac{1}{\tau_i})},$$

where $Slope_{t,n}$ s the time-weighted average of slope in an day t interval n. To understand the equation (4): on the one hand, the first term in the bracket is the slope from the midpoint to the best ask price level in a tick. In other words, the first term measures the percentage of size at the best quote to the change of best ask price relative to the mid-price. The second term in the bracket is the sum of the slopes for the rest levels in that tick. For each level, slope is the elasticity that measures the change of sizes relative to the last level to the change of prices relative to the last level. In summary, we measure the percentage change of size at every price level compared to the size of the previous level in a tick. In other words, we measure the elasticity of size with respect to in a tick.

Note that the first term and the second term are not measured in the same units. (Naes & Skjeltorp, 2006). Since the size at the midpoint is unobtainable. We cannot calculate the elasticity of the first term. In section 6, we summarize several different measures of slope as a robustness test of slope measure.

So we have defined the slope, depth and quoted spread of the LOB and refer to these three characteristics as "liquidity characteristics" where each measures the liquidity of the LOB in different ways. Another reason to differentiate them from the volatility is that the intraday seasonality patterns are different. In other words, the intraday seasonality patterns of liquidity characteristics are similar, but are different

from the volatility intraday seasonality pattern. In the last part of section 3.2, we define the variation of the prices in LOB as the volatility for the LOB return. In 3.2.4, we define the mid-price of LOB then define the return volatility.

3.2.4 ***The Volatility***

Kozhan and Salmon (2010) demonstrate the economic value of LOB information in FX markets by using the full book. In this paper, they use size-weighted price to calculate the mid-price and spread. In other words, the mid-price and spread combines all the levels of the LOB. We follow Kozhan and Salmon (2010), and compute the size-weighted average price of LOB. Compared to the methods that use the best quote price to calculate the return, the method by Kozhan and Salmon (2010) combine the size and prices of all levels in one tick.

The average ask price at tick i in interval *n* is

$$AP^{A}{}_{n,i} = \frac{\sum_{l=1}^{L}[Q^{\boldsymbol{A}}_{n,i,l} \times P^{A}_{n,i,l}]}{\sum_{l=1}^{L} Q^{\boldsymbol{A}}_{n,i,l}}, \tag{5}$$

where $AP^{A}{}_{n,i}$ is the size-weighted average ask price at tick *i* in interval *n* and denote $Q^{\boldsymbol{A}}_{n,i,0} = 0$. Likewise, we denote $AP^{B}{}_{n,i}$ as the average bid price at tick *i* in interval *n*. The size-weighted price means that the price at each level is weighted by the percentage of the corresponding size on that level to the total size of all levels in that tick. Denote $MID_{n,i}$ is the average mid quote price at tick *i* in interval *n*: $MID_{n,i}=\frac{AP^{A}{}_{n,i}+AP^{B}{}_{n,i}}{2}$.

The mid-quote price at tick *i* in interval *n* is:

$$MID_{t,n} = \frac{\sum_{i=1}^{\gamma n}[(\frac{1}{\tau_i})\times MID_{t,n,i}]}{\sum_{i=1}^{\gamma n}(\frac{1}{\tau_i})},$$

where $MID_{t,n}$ is the time-weighted average of mid-quote prices in interval *n* on day *t*. We calculate the return based on the mid quote. Following Andersen and Bollerslev (1998), the return in interval *n* at sample day *t* is: $R_{t,n} = \left(log\left(MID_{t,n+1}\right) - log\left(MID_{t,n}\right)\right) \times 100$, where $R_{t,n}$ is the return over the 5-min interval n=1,2,…, N for sample day t=1,2,3,… T. Then we obtain the absolute centered 5-min return structure$\left|R_{t,n} - \bar{R}\right|$, denoted here as *Abs_return*, where $\bar{R}$ is the average return for whole sample.

3.3 VAR with Two-regime Smooth Transition Regression

Using data of Dow Jones (DJIA) stocks, Nigmatullin, Tyurin, and Yin (2007) show that the significant interactions exist among characteristics of LOB in a Vector Auto Regression (VAR) model. Following Nigmatullin, Tyurin, and Yin (2007), we construct a model to analyze the effect of macro news on the characteristics in the LOB in business cycles. In other words, we use a VAR model to describe the joint dynamics among the characteristics with macroeconomic news being exogenous variables. To be specific, we construct a VAR model with *j*-lagged endogenous variables, VAR (*j*).

In the section 3.3.1, STR is introduced into VAR for measuring the effect of macro news on characteristics in different economic cycles. In the section 3.3.2, we

construct a VAR-STR model to estimate the effects of the news surprise in different economic cycles. The estimation methods of the effect of pure news and aggregated good and bad news are introduced in section 3.3.3 and 3.3.4.

3.3.1 *Two-regime Smooth Transition Regression*

We follow Laakkonen and Lanne (2010) to detect the regime transition by applying the two-regime logistic smooth transition regression (LSTR) (Teräsvirta, 1994). The LSTR is:

$$Volat_{t,n} = \alpha_1 + \sum_{j=1}^{J} \beta_j \Gamma_{t,n-j} + \{\alpha_2 + \sum_{j=1}^{J} \beta_j' \Gamma_{t,n-j}\} G(\psi_{t,n}, \gamma, c) + \varepsilon_{t,n}, \quad (6)$$

with $G(\psi_{t,n}, \gamma, c) = \frac{1}{1+EXP[-\gamma \prod_{k=1}^{K}(\psi_{t,n}-c_k)]}, \Upsilon > 0.$ (7)

Denote $Volat_{t,n}$ as the log-transformed filtered volatility on day *t* and interval *n* after the filter for intraday seasonality effects and daily ARCH effects; and $\Gamma_{t,n-j}$ includes consolidated macroeconomic news. The common choice of *k* is either one or two. If *k*=1, this is a logistic STR1 model. Transition function $G(\psi_{t,n}, \gamma, c)$ is a logistic function of the continuous transition variable $\psi_{t,n}$. The transition variable is represented by ISM index figures[3]. The model implies transition between two economic regimes: higher regime ($G(\psi_{t,n}, \gamma, c)$=1 when $\psi_{t,n} > c$), and lower regime ($G(\psi_{t,n}, \gamma, c)$=0 when $\psi_{t,n} < c$), where γ is the shape parameter, *c* is the location parameter, and *k* is the transition function scale. If the shape parameter γ is high, this indicates a sudden transition happened during the sample period.

[3] To estimate the regime transition for U.S. crisis, we choose the corresponding transition variable based on the ISM (Institute for Supply Management) manufacturing index for US business cycles.

3.3.2 *VAR-STR for Surprise*

First we model the characteristics' response to the news surprise based on the VAR model with exogenous variables. Surprise measures the magnitude of news effect. In this case, there are three types of exogenous variable in the model, the news surprise of macroeconomic news, and a seasonality dummy for liquidity characteristics.

Then, after the identification of economic regimes in the sample, we introduce the US crisis in a VAR model by imposing the fitted logistic transition function $\hat{G}(\psi_{t,n}, \gamma, c)$. Then we combine the VAR and STR models in the case of a news surprise. With l lagged values in the characteristic variables, the VAR-STR model in matrix notation is:

$$\Omega_{t,n} = \alpha_{t,n} + \sum_j^J \beta_j \Omega_{t,n-j} + \lambda AV_{t,n} + \sum_{q=1}^Q \theta_q S_{q,t,n} + \eta_1 unsch_{t,n}^{US} + \eta_2 unsch_{t,n}^{EC} + \{\alpha'_{t,n} + \sum_{q=1}^Q \theta'_q S_{q,t,n} + \eta'_1 unsch_{t,n}^{US} + \eta'_2 unsch_{t,n}^{EC}\}\hat{G}(\psi_{t,n}, \gamma, c) + \varepsilon_{t,n} \quad (8)$$

where characteristics $\Omega_{t,n}$ is a vector of endogenous variable which represents one of four characteristics as the vector of dependent variables. Hence the vector of endogenous variables in (8) is: $\Omega_{t,n} = (Depth_{t,n}, Slope_{t,n}, Qspread_{t,n}, Volat_{t,n})'$, where $Depth_{t,n}$ is the depth at interval *n* on day *t*; $Slope_{t,n}$ is the slope at interval *n* on day *t*; $Qspread_{t,n}$ is the quoted spread at interval *n* on day *t*; and $Volat_{t,n}$ is the filtered volatility at interval *n* on day *t*. $\alpha_{t,n}$ and $\alpha'_{t,n}$ are vectors of the constant (intercepts). $\varepsilon_{t,n}$ is the error term. β_j is coefficient matrix of $\Omega_{t,n-j}$ and λ is the

coefficient matrix of vectors of seasonality dummies. Lag $j = 1,2, \dots, J$[4] is decided by AIC and BIC criteria.

When liquidity characteristics (depth, slope or quoted spread) are dependent variables respectively, each dependent variable has its corresponding seasonality dummy as an exogenous variable to control the effect of intraday seasonality in estimation. We denote the intraday seasonality dummy for liquidity characteristics as $AV_{t,n}$ which represents one of the vectors of the seasonality dummy of liquidity characteristics: quoted spread, depth and slope respectively. The vector of the seasonality dummy of liquidity characteristics is: $AV_{t,n} = \left(AV_{t,n}^{depth}, AV_{t,n}^{qspread}, AV_{t,n}^{slope}\right)'$. The seasonality dummy of quoted spread, depth and slope are $AV_{t,n}^{depth}$, $AV_{t,n}^{qspread}$ or $AV_{t,n}^{slope}$ respectively. Note that $AV_{t,n}$ is a regressor when liquidity characteristics are endogenous variables only. We use the IAOM method to construct the "seasonality dummy" of three liquidity characteristics. For volatility, we use FFF method to filter out the intraday seasonality in volatility. The filtered method of liquidity characteristics and volatility is also in section 3.4.

Denote the news categories $q = 1,2,3, \dots, Q$, where q indicates the one of categories of macroeconomic news and Q is the total number of macroeconomic news announcements in the sample. $\hat{G}\left(\psi_{t,n}, \gamma, c\right)$ is the fitted value of logistic transition variable in LSTR. Following the method by Balduzzi Elton and Green (2001), we denote $S_{q,t,n}$ as the news surprise for news category q in interval n on

[4] Using AIC and BIC criteria, the results indicate that a 1-lag structure (j=1) is adequate we estimate a VAR(1) with four variables.

day *t*. The calculation of news surprise is shown in section 4. The surprise vector of coefficients is denoted as θ_q; the transition vector of surprise coefficients is denoted as θ_q'. We also consider unscheduled new related to the US crisis as the other two exogenous variables. One is unscheduled news related to crisis for the US and the other is unscheduled news related to the European crisis. $unsch_{t,n}^{US}$ is the US unscheduled news and $unsch_{t,n}^{EC}$ is the European unscheduled news. The vector of coefficients of unscheduled news related to the US and EC crisis are denoted as η_1 and η_2, respectively; the other two coefficients vector of unscheduled news with respect to the transition variable are denoted as η_1' and η_2' respectively.

3.3.3 *VAR-STR for Pure News*

We construct the STR model to examine the effects of pure news on characteristics in different regimes. Pure news is different from the news surprise and the VAR-STR model with pure news as exogenous variables is:

$$\Omega_{t,n} = \alpha_{t,n} + \sum_j^J \beta_j \Omega_{t,n-j} + \lambda AV_{t,n} + \sum_{q=1}^{Q} \xi_q Pure_{q,t,n} + \eta_1 unsch_{t,n}^{US} + \eta_2 unsch_{t,n}^{EC} + \left\{\alpha_{t,n}' + \sum_{q=1}^{Q} \xi_q' Pure_{q,t,n} + \eta_1' unsch_{t,n}^{US} + \eta_2' unsch_{t,n}^{EC}\right\}\hat{G}(\psi_{t,n}, \gamma, c) + \varepsilon_{t,n} \quad (9)$$

where $Pure_{q,t,n}$ denotes the pure news of category q in interval n at day t. ξ_q is the coefficient vectors of pure news of category q at date t and interval n, the other vector of pure news coefficient with the effect of the transition variable is denoted as ξ_q'.

3.3.4 *VAR-STR for Aggregated Good and Bad News*

We construct aggregated dummy for "good" news and "bad" news. So the VAR-STR model with aggregated "good" and "bad" news as exogenous variables is:

$$\Omega_{t,n} = \alpha_{t,n} + \sum_j^J \beta_j \Omega_{t,n-j} + \lambda AV_{t,n} + \rho_g Good_{t,n} + \rho_b Bad_{t,n} + \eta_1 unsch_{t,n}^{US} + \eta_2 unsch_{t,n}^{EC} + \{\alpha'_{t,n} + \rho'_g Good_{t,n} + \rho'_b Bad_{t,n} + \eta'_1 unsch_{t,n}^{US} + \eta'_2 unsch_{t,n}^{EC}\}\hat{G}(\psi_{t,n}, \gamma, c) + \varepsilon_{t,n} \quad (10)$$

where $Good_{t,n}$ denotes the aggregated "good" news in interval *n* at day *t*. $Bad_{t,n}$ denotes the aggregated "bad" news in interval *n* at day *t*. ρ_g and ρ_b are the coefficients vector of aggregated "good" and "bad" news in interval *n* on day *t*.

3.4 Intraday Seasonality

In this section, we introduce filter methods for the intraday seasonality pattern. For liquidity characteristics (slope, depth and quoted spread), we use the intraday average observation model (IAOM) to construct control dummies for seasonality (Omrane and Bodt, 2007). For volatility, we use Flexible Fourier Form (FFF) to filter the seasonality (Anderson et al., 2003).

3.4.1 *Intraday Seasonality Patterns of Liquidity Characteristics*

For the spread, depth and slope, we adjust each variable for its intraday seasonality by using the intra-day average observations model (IAOM) (Omrane and Bodt 2007). The control dummies for three characteristics become exogenous variables in the VAR to capture the intraday periodicity of those liquidity characteristics. We remove all the intervals that belong to the following dates:

Monday, Tuesday, Wednesday, Thursday and Friday, and exclude non-trading dates: Saturday and Sunday. So we get five sub-sets of the sample data, one for each weekday. Then calculate the simple average of corresponding characteristics for each subset to get intra-day average observation for each interval in a trading day. Finally, we construct the control dummy with the value of the intra-day average for all the intervals in the five weekdays respectively. The corresponding exogenous control dummies for endogenous variables $Depth_{t,n}, Slope_{t,n}$ and $Qspread_{t,n}$, are quoted spread $(AV_{t,n}^{depth})$, depth $(AV_{t,n}^{qspread})$, and slope $(AV_{t,n}^{slope})$.

3.4.2 *Intraday Pattern of Volatility*

The return volatility is also strongly correlated to market activities as Andersen & Bollerslev (1998) conclude that the return volatility is affected by intraday activity patterns. So we adjust our model to eliminate the influence of intraday seasonality patterns.

Following Andersen & Bollerslev (1998), we decompose the volatility as: $\left|R_{t,n} - \bar{R}\right| = \frac{\sigma_t}{\sqrt{N}}$ where $\bar{R}$ is the sample mean return of $R_{t,n}$. $\frac{\sigma_t}{\sqrt{N}}$ represents a daily ARCH effect, σ_t denotes the AR (2)-GARCH (1, 1) one day ahead daily volatility[5], N is the total number of 5-min intervals per day. Then square and take natural log on both sides to obtain $2\ln\left(\frac{\left|R_{t,n}-\bar{R}\right|}{\frac{\sigma_t}{\sqrt{N}}}\right) = 2\ln\left(h_{t,n}\right) + 2\ln\left(v_{t,n}\right)$, where $h_{t,n}$ denotes the intraday seasonality and $v_{t,n}$ contains the rest of the volatility including

[5] Appendix B shows the computation method of one day ahead volatility.

announcement effects. Next, we estimate the cyclical volatility component and use Flexible Fourier Form (FFF) regression to get $\hat{f}_{t,n}$:

$$f_{t,n} = \mu + \delta_1 \frac{n}{N_1} + \delta_2 \frac{n^2}{N_2} + \sum_{d=1}^{D} \lambda_d I_d(t,n) + \sum_{p=1}^{P} \left(\delta_{c,p} \cos\left(\frac{2\pi p}{N} n\right) + \delta_{s,p} \sin\left(\frac{2\pi p}{N} n\right)\right) + \varepsilon_{t,n} \quad (11)$$

where $f_{t,n}$ is the log-transformed volatility and $f_{t,n} = 2\, ln\left(\frac{|R_{t,n} - \bar{R}|}{\sigma_t/\sqrt{N}}\right)$; μ is constant; $\frac{n}{N_1}$ and $\frac{n^2}{N_2}$ are normalizing factors, here n is the number of interval where $N_1 = \frac{N+1}{2}$ and $N_2 = \frac{(N+1)(N+2)}{6}$. Normalizing factors are used to control for holiday effects, weekday effects etc. $\bar{R}$ is the expected intraday returns for size-weighted mid-price. In addition, σ_t denotes one day ahead daily volatility in a GARCH (1, 1) model using the interval return[6]. $I_k(t,n)$ is an indicator for the event d during interval n on day t. $I_k(t,n)$ captures the calendar effects: Japanese open, Japanese lunch and the U.S. late afternoon during U.S. daylight saving time. For Japanese open events, a polynomial structure with the single order for 2 hours is used to capture the increased log-volatility when Japan opens; and a second order polynomial structure is applied to capture the volatility decay pattern for the summer regime. The sinusoids denotes the Flexible Fourier Form that provides the approximation of the intraday periodicity pattern. Choose *p* according to Schwarz and Akaike Information Criteria[7]. In order to capture the deterministic and time varying seasonality components, the FFF estimation is done in sequential sub periods of four weeks.[8]

[6] The estimate of one-day-ahead volatility is forecasted based on the daily volatility from January 11, 2004 through December 31 2009.

[7] According AIC, p=1;

[8] We considered sub periods of one and two weeks but estimated results were not statistically significant.

The estimate of the normalized intraday seasonality is computed as $\hat{s}_{t,n} = \frac{\exp\left(\frac{\hat{f}_{t,n}}{2}\right)}{\bar{s}_{t,n}}$, where $\hat{f}_{t,n}$ are the fitted values of the model. This estimate $\hat{s}_{t,n}$ is normalized so that the mean of the normalized seasonality estimate equals one: $\bar{s}_{t,n} = \frac{T \times \hat{s}_{t,n_k}}{\sum_{t=1}^{T/N} \sum_{n=1}^{N} \hat{s}_{t,n_k}}$, where T is the number of observations in the whole sample. Following Andersen and Bollerslev (1998), the original volatility $R_{t,n}$ is then divided by the normalized estimate $\bar{s}_{t,n}$ to compute filtered returns: $\hat{R}_{t,n} = \frac{R_{t,n}}{\bar{s}_{t,n}}$. Finally, the filtered volatility for VAR regression is: $Volat_{t,n} = 2ln\frac{|\hat{R}_{t,n} - \bar{R}|}{\sigma_t/\sqrt{N}}$, where $Volat_{t,n}$ is filtered volatility based on the return calculated by size-weighted mid-price of the LOB.

4. Data

4.1 Limit Order Book

The original book is obtained from Hotspot FXi. The book contains quote tick-by-tick data from Jan 3rd 2006 to Dec 31st 2009. The original LOB records limit orders of exchange rates and size for Euro/Dollars. Each tick in the LOB is stamped as milliseconds in Eastern Standard Time (EST) adjusted daylight saving time. Diagram 1 shows a simple example of a single update in the LOB. For example, four levels at the ask side and three levels at the bid side of the first tick (*i*=1) in interval *n*=2. For each level in the LOB, the price of that level and the corresponding size is given. The best ask is the lowest ask price which is denoted as ask price level *l*=1 and similarly the best bid is the highest bid price, denoted by bid price level *l*=1.

To demonstrate the LOB liquidity condition in different phases of economy, we choose up to two months of the LOB before and during the crisis according to Figure 4 which shows the estimated economic transition regimes for the sample period. One is January of 2006 (Panel A of Table 1), the other is April of 2009 (Panel B of Table 1). Table 1 shows the descriptive statistics of ask and bid side of the LOB in the different stages of the business cycles. To measure the intensity of trading activity, we calculate the number of levels in a tick and the number of ticks in a 5-min interval. In January 2006, there are about 340 ticks per interval for both ask and bid sides. In the most intensive hour, the number of ticks can soar to 1134 per 5 minute interval, while the most inactive hours has only one tick. These facts indicate the disparity of the trading intensity of the FX market in a day. Compared to the situation of January 2006, the LOB is illiquid during the crisis (April 2009). The average number of the ticks in a 5-min interval is 289 with a maximum of 572 for both the ask and bid sides. To measure the "deepness" of the book, the number of levels in a tick is listed in the table. For January 2006, the mean number of tick level for both sides is 9 with a maximum of 22, compared to 23 in April 2009. The maximum number of level in a tick for the ask side is 45 and compared to 49 for the bid side, which is around twice the number in January 2006.

Size is another aspect to measure the LOB liquidity situation. Table 1 shows the size of the best quote and the size of the whole book in one tick. Generally speaking, the size in one tick before the crisis (January 2006) is much larger than the size of a

tick during the crisis (April 2009). In the ask side, the size in a tick in Jan 2006 is 75900682 with an average level of 9 which is larger than in April 2009 (66115081with average level of 23). Also, the size is more centrally distributed near the best quote before the crisis compared to that during the crisis, which indicates a steeper size curve. The best size on ask side is 17% of the total size in the LOB for January 2006, compared to 5% on the ask side in April 2009. Table 1 also list the spreads for both months. The spread is the difference between the best ask and bid prices. The average of the spread in the 2006 (0.00018) is a bit larger than that in April 2009 (0.00016).

4.2 Interval Data

We resample the data with equally-divided-intervals instead of using tick-by-tick data and choose 5-min intervals as a compromise between information and noise. Since each quote is time stamped to milliseconds, the first interval of a trading day is 00:00:00.000 EST to 00:04:59.999 EST. Hence for one trading day, the time goes from 00:00:00.000 EST to 23:59:59.999 EST. The sample data only includes trading days (no weekends) and we exclude the outlier interval from 5:00 PM to 5:40 PM as well as ten important US statutory holidays[9]. The first interval (00:00:00.000 EST to 00:04:59.999 EST) is deleted to avoid overnight effect. The data sets for estimation include intraday 5-min interval euro/dollar exchange rate data and macroeconomic news data from Jan 3rd 2006 to Dec 31st 2009.

[9] The Ten US statutory holidays deleted are: New Year's Day, Martin Luther King's Day, Presidents Day, Memorial Day, Independence Day, Labor Day, Columbus Day, Veterans Day, Thanksgiving Day and Christmas Day.

Table 2 provides the summary statistics for characteristics in an interval. Excluding the outliers and important holidays, we have 245,780 intervals in sample years from 2006 to 2009. Note that these characteristics are not adjusted for intraday patterns. The volatility based on the size-weighted average price is denoted as "*Abs_return*". The average of the volatility is 0.02% with a maximum 11.41%. The other method introduced in section 6 is denoted as "*Abs_ret*", which has an average of 0.03% with a maximum of 8.08%. Table 2 also lists the descriptive statistics of two depth measures (Depth and size), two spread measures (Qspread, sizespread) and three slope measures (slope, NORM SLOPE, WSLOPE). We show the autocorrelation of each characteristic up to 2 lags. The null hypothesis that no autocorrelation exists is rejected and the autocorrelation coefficients of all the characteristics are significant at 2 lags.

Table 3 shows the summary statistics of standardized characteristics and Table 4 presents the correlations between standardized characteristics used in VAR-STR regression. We standardized the liquidity characteristics (depth, size, slope, NORMSLOPE, WSLOPE, quoted spread and size-weighted spread) with their corresponding standard deviation. Focusing on the four characteristics we introduced in section 3, we find depth is negatively related to the quoted spread, slope and volatility, which agrees with the Ahn et al (2001). As shown in the Naes and Skjeltorp (2006), volatility is negatively related to the slope. The correlation between quoted spread and slope is negative, while quoted spread is positively related to volatility. In

addition, the t-test is conducted on these correlations with the null hypothesis that the correlation between variables are zero which are all significant.

4.3 Macroeconomic News

The macroeconomic news data include scheduled and unscheduled news. There are 89 categories of news announcements in different countries and regions in our sample from 2006 to 2009.

4.3.1 *Scheduled News*

Supported by Bloomberg, the scheduled macroeconomic news includes the news announcements from US, Euro Zone, Germany, France, Italy, Spain, and Poland. Usually, news is released weekly, monthly and quarterly. We exclude news with very few observations or missing actual or forecast values.

a. News surprise

Bloomberg provides both actual and market forecasts of news announcements. The market forecasts are the median value of the survey, which is conducted before the release day. We consider both actual figures and forecasts by using the news surprise, which is measured in Balduzzi, Elton and Green (2001). The news surprise is the difference between the forecast and the actual figure and then dividing this difference by the standard deviation of these differences:

$$S_{q,n} = \frac{A_{q,n} - F_{q,n}}{\hat{\sigma}_q}$$

where $A_{q,n}$ the actual figures of news q at interval n is, and $F_{q,n}$ is the forecasts for the corresponding announcements. $\hat{\sigma}_n$ is the sample standard deviation of the

difference between actual and forecast for news q considering in the sample. The news surprise measures the response of the market to the news.

b. Pure News

To measure the effect of a news occurrence, a "pure news" dummy is created for every category of scheduled macroeconomic news with different countries. The dummy variable is one when news happens, otherwise it is zero. In all, we have 3452 news surprises of news announcements and 89 news categories. The news surprise is 0 when the actual figure of news equals to the forecast for the news. Even if news surprise is zero, a news event still happens. In 3452 news surprises, 444 have news surprise of 0. In other words, we lose 13% of news in the estimation of the VAR-STR model. So pure news can make up the 13% loss from the news surprise. The surprise news can measure the magnitude of news effect, while pure news only catches the event itself.

c. Aggregated News

Besides the news surprise and pure news, aggregated news is applied in the VAR-STR model to show the aggregated effect of news on the LOB characteristics. Under the assumption that news effects can be aggregated, we construct a dummy for aggregated news. We classify the news as "good" and "bad" for each category of news announcement. "Good" news has a positive effect (appreciation) on currency. "Bad" news has a negative effect (depreciation) on currency. We adjust some news according to the meaning of the news, for example, when the unemployment rate is

underestimated, this indicates "bad" news. Then we aggregate all the "good" news into a dummy of 1 for "good" news and 0 otherwise. Similarly, we construct the dummy of aggregated "bad" news: 1 for "bad" news and 0 otherwise.

d. Filter Rules

With missing observations excluded in the first round of filters, we also have to delete some news during the estimation process of VAR-STR. During the analysis, we have to filter the news that leads to multicollinearity issues in regression equations. Usually, the news that is deleted in this step has a linear correlation with other variables in the regression. The news that has a significant coefficient in the contemporaneous regression (Andersen et al., 2003) is kept.

Based on the estimation process, Table 5 summaries the number of news after filtering. In all, we have 89 categories of news. In the case of VAR-STR estimation on the news surprise, only one news in the EC is deleted. For the case of pure news, the news dummy caused more singular matrix issues and 15 news are deleted. As shown in the Table 5, with 3452 observation of the news announcements, only 2299 (67%) are applied in the estimation. In the case of regression of pure news, 67% of 89 news categories are used.

4.3.2 *Unscheduled News*

Previous literature points out that unscheduled news effects should be controlled in the forex market (Bauwen, Ben Omrane & Giot, 2005). Unscheduled News related to the Crisis is constructed based on the dates of the US crisis from Federal Reserve

Bank of New York. The time line mark the days for important news related to a crises. A dummy series was constructed with one for days with important news and zero otherwise.

5. Empirical Results

In this section, first we analyze the intraday seasonality pattern of the characteristics. Then we show the estimation results of VAR-STR model to surprise, pure news and good/ bad news.

5.1 Characteristics Analysis

LOB Characteristics have intraday seasonality patterns and time periodicity reflects the fact that the FX market trade in different time zones around the world during a day. In general, there are two kinds of patterns of figures. One is the pattern of liquidity characteristics, while the other is the volatility seasonality pattern. The detailed method dealing with this seasonality is given in the section 3.

The intraday pattern of the four characteristics is plotted in Figure 1 using the average for every interval during the sample. Figure 2 shows the cluster of news in a day for euro zone countries[10] and the US. Depth gradually increase often from the midnight, that is, 00:05 EST, but stays at a relatively low level when the London and New York markets are closed. Then the depth curve goes up after 2:00 EST when several European markets are open. When the New York Market opens, the depth

[10] The news euro countries: EC, FR, GE, IT, PO and SP.

reaches a higher level with two downward plunges around 8:00 and 10:00 EST which agrees with the announcement times of most news. Then depth gradually declines to reach its lowest level just after 17:00 EST when the New York market closes. After 17:00 EST, only a few markets in Asia and Australia are open. Although the activity gradually increase after five, it stays lower than the amount during the daytime in EST.

The intraday pattern for the quoted spread (Figure 1.b) experiences on opposite tendency compared to depth. The quoted spread gradually goes down, and stays in a relatively low when London and New York market are closed. When the majority of US news announcements happen around 8:00:00 EST and 10:00:00 EST giving the quoted spread two sudden peaks. After that, the European Markets start to close and the quoted spread gradually increases to its peak right after New York market closes.

The slope intraday pattern tends to be more stable (Figure 1.c). Around 2:00 EST, the slope gradually goes up and stays a high level with downward fluctuations around 8:00 EST and 10:00 EST, which considers with the majority of news announcements. Then the slope gradually reaches its peak around 17:00:00 EST when New York closes, indicating that the slope reaches its highest level of the day when the trader aggressiveness is high. After 17:00:00 EST, the slope decreases dramatically and stays relatively low.

The intraday pattern of volatility is shown in Figure 1.d. In addition, the volatility quickly goes up, and reaches its first peak around 3:00 EST when the London market

opens. After that, volatility peaks around 8:00 EST and stays at a high level until 11:00 EST. Then the volatility experiences a declining undulation to reach its lowest point at time when New York closes.

In section 3, we introduced two methods for controlling or eliminating these intraday patterns. In the case of liquidity characteristics, we use IAOM to construct average control dummies which are used in the estimation to capture the intraday pattern of depth, slope and quoted spread. In the case of volatility, we use FFF regression to eliminate the intraday pattern in the volatility (Andersen & Bollerslev, 1998). In addition to the volatility introduced in the section 3, *Abs_return*, we do a robust check by using the volatility based on the best quote, *Abs_ret* (section 6.1.4). FFF regression is applied in both two volatility measures.

Figure 6 plots the autocorrelation coefficients of filtered and original volatility. To present the periodicity pattern in the auto correlogram, we plot the autocorrelation coefficients of the original volatility in 5 days[11]. As shown in panel A in Figure 6, the autocorrelation coefficients of *Abs_return* shows a regular rising and falling after going through a more intense fluctuation in its starting phase while in panel B, the autocorrelation coefficients of *Abs_ret* before filtering moves in a regular wave. Although filtered volatility is still auto correlated, the filtered volatility for both *Abs_return* and *Abs_ret* moves stably around 0, implying that the FFF regression eliminates the intraday seasonality pattern of the *Abs_return* and *Abs_ret*.

[11] We calculate the autocorrelation of the original volatility for 1400 lags.

5.2 Estimation Results of the Logistic Transition Function in STR model

According to Veredas (2006), the ISM index is used as business cycles indicators for regime transition effects and is more informative and accurate than NBER in Laakkonen and Lanne (2010). ISM higher than 50 indicates that economy is in expansion (good times). The ISM plot for 2006 to 2009 is in Figure 3. The ISM falls below 50 between the fall of 2008 to the fall of 2009. Although the ISM fluctuates during 2006 and the end of 2007, it does move above 50, indicating the majority practitioners hold a positive opinion about the business condition during that stage. Figure 3 indicates that the US crisis starts around the fall of 2008, when ISM is under 50 and sharply decreases.

Table 6 shows the estimation results of equations (6) and (7). We use ISM as a regime transition indicator for the US crisis in the logistic transition function, equation (7), to obtain the fitted value of *G*. LSTR1 model indicates that two regimes exist in our sample period. The significant shape parameter γ is 4.111, implying a switch from regime 1 to regime 2. β represents the news effect of filtered volatility during recession, and $\beta + \beta'$ represents the new effect of filtered volatility during expansion. From Table 6, the significant coefficient of consolidated news β' also indicates that the news effect is significantly different between the regimes 1 and 2.

Figure 4 plots fitted G and NBER dates in our sample range. The NBER date shows the recession started in the fall of 2007 and ended in the beginning of 2009. NBER only provides the information about the start and end dates, but ISM is

continuous which can be used in any sample to identify the business cycles. According to the plot of fitted *G* in figure 4, the economy starts going through a sluggish time from the beginning of 2007. After a slight resurgence period in 2008, the economy starts the next round recession in the fall of 2008 and end in the mid of 2009. Then the economy starts to recover in the fall of 2009. The STR provides a more detailed timeline of the business cycles.

5.3 News Surprise Effects over Business Cycles

Table 7 presents estimation results of the news surprise effect on LOB characteristics. Table 12 accumulates the number of significant news surprises in each country. For volatility, 17% of 89 news categories are significant in the recession and 21% of 89 news categories are significant in the expansion. So volatility is more affected by news surprise during the expansion. Besides US and EC news, volatility is affected by news from German, Italy and Spain. With respect to other significant news in the recession, housing related news announcements, such as Existing Home Sales and NAHB Housing Market Index, positively affect volatility. This result is supported by the fact that the US crisis originated from housing subprime crisis. News announcements related to production, price index and employment, such as GDP Annualized QoQ Advance, Core PCE QoQ and ADP Employment Change, negatively affect volatility during the expansion. We find that some news announcements have significantly different effects in both regimes, such as, Labor Costs, NAHB Housing Market Index, ISM-Non-Manf. Composite, Nonfarm

Productivity – Final and PCE Core MoM. This finding agrees with the state-dependent effects documented by Ben Omrane & Savaser (2013), which shows that the news effects vary with the economic states.

In Table 12, almost half of types of news are significantly related to depth as 45% types of news in recession and 57% types of news in expansion are significant. So depth is more affected by news surprise during an expansion. Besides the US and Euro zone, news from Germany and Italy also has significant impacts on depth. News announcements related to forward looking and monetary policy positively affect depth during expansion, such as, Business Climate Indicator and FOMC Rate Decision. We find that 24% of 89 news have significantly different effects in both recession and expansion, indicating the news effects on depth are state-dependent. Normally, depth will decrease around news announcements as conservative traders will provide more limit orders with a "thin" book (Erenburg and Lasser, 2009). However, our estimation shows that the sign of the news depends on the specific content of the news. News related to housing markets are significant in both regimes: New Home Sales, Pending Home Sale MoM, Housing Starts, Existing Home Sales and NAHB Housing Market Index. Personal-consumption-related news announcements cause depth fluctuations: Personal Consumption- Preliminary, Personal Spending, and Private Consumption QoQ. Depth is significantly affected by ISM Manufacturing and Consumer Confidence Index in both regimes, implying that traders rely on the forward looking news to make decisions. Notably, some

state-dependent news announcements have opposite effects in two business regimes. For example, the unemployment rate is negatively related to depth in a recession while positively related in an expansion.

From Table 12, quoted spread is more affected by news surprise during expansion. Significant news are from EC US and GE. In the recession, news announcements used as price index are significant, such as CPI Estimate YoY. Income related news announcements positively affect quoted spread. In the expansion, forward looking news has negative effects on quoted spread, such as consumer confidence index. The quoted spread negatively reacts to news related to personal consumption: Personal Consumption and Personal Spending. Housing market news also affects quoted spreads: Housing Starts, Pending Home Sales MoM. For quoted spread, 13% of news announcements have state-dependent effects as unemployment rates is negatively related to quoted spread, regardless of regimes. Some of state-dependent news announcements have opposite effects in two business regimes. That is, the sign of coefficients of ISM Manufacturing, Housing Starts and Initial Jobless Claims changes over different economic stages.

For slope, 21% of news announcements are significant in the recession while only 3% of news is significant in the expansion, implying an asymmetric slope news response to economic cycles. During the recession, slope is mainly affected by news of Euro Zone, Germany and US while in the expansion, only US news affects slope. News announcements related to forward looking, employment, monetary policy are

significant during the recession, such as ISM Manufacturing, FOMC Rate Decision, and Unemployment Rate. In the expansion, news related to income has negative impacts on slope, such as Change in Nonfarm Payrolls.

Table 7 also exhibits the estimation results of unscheduled news related to crisis in the case of news surprise. US Unscheduled news has oppositely significant effect on all characteristics. EC unscheduled news also has significantly different effect on all characteristics.

5.4 Pure News Effects over Business Cycles

Table 8 shows the estimation results of pure news effects. Table 12 panel B shows the percentage of significant pure news for the characteristics. The total number of significant news in equation (9) is more than that in equation (8) although only 74 news announcements are estimated in equation (9). This is caused by the difference in regression objectives between pure news, and its news surprise. While the surprise regression captures the magnitude of news effect, while the pure news regression tries to capture the number of significant news announcements. The 13% difference occurs because there is no surprise when actual equals expectations.

Contrary to surprise, more types of news are significant during expansion in the case of pure news. During the expansion, significant news are primarily in the US. In euro countries, volatility is more affected by German macro news during the recession. News positively affects volatility during the recession, such as, ECB announcement of interest rates, the University of Michigan Confidence preliminary and consumer

confidence index. Volatility also responds to news related to the business environment during the expansion: Philadelphia FED business outlook and IFO business climate. We find that 10% of news announcements have state-dependent effects. The release of FOMC rate decisions triggers a growth in volatility in both regimes. Similar to news surprise, housing starts and existing home sales all positively affect volatility in both regimes.

Depth in equations (8) and (9) both react to more than half of the news categories. Similar to the case in (8), more types of pure news affect depth during expansion where 71% of news are significant. Similar to the case in (8), significant news are evenly distributed among all the regions in expansion period. Depth responds to 47% of pure news with state-dependent effects. In general, news announcements related to housing markets, monetary policy, price index, personal consumption, income, and forward looking have significantly positive effects on depth in both regimes. For instance, the occurrence of housing starts, new home sales and pending home sales MoM leads to a significant increase in depth. And depth experiences a growth in recession and expansion when initial jobless claims, IFO business climate, PCE core MoM are released.

According to Table 12, for the quoted spread in equation (9), the pure news effect in recession (30%) is weaken than in expansion (42%). Similar to the other characteristics, the quoted spread is strongly affected by news that are related to housing market: new home sales, housing starts and pending home sales MoM have

significant negative effects on quoted spreads. The quoted spread decreases in response to the release of price index during the recession. We find that 17% of news announcements have state-dependent effects and almost all of them are negatively related to quoted spread. News related to credit, employment and customer confidence have significantly different effects in recession and expansion. Notably, ISM Manufacturing has a significant opposite effect in recession versus expansion.

Slope is rarely significant for any news category but it has larger response to pure news during recession compared to expansion. In general, the pure news effect on slope is weaker than the news surprise. All significant news are positively related to the slope during recession except the business climate indicator. The release of New Home Sales is positively related to slope during expansion. Note that the sign of coefficient of Chicago Purchasing Manager changes over business cycles while Average Hourly Earnings MoM positively affects slope in both regimes.

In summary, two types of news are likely to affect four characteristics in both regimes. The first type is strongly related to the crisis context. For instance, among the four characteristics, the frequency of significant news related to housing market is higher than that of the other type of news, which may be related to the fact that the crisis originated from the US subprime mortgage market. The other type is the news that are economic indicators, such as ISM manufacturing, unemployment rate and personal consumption.

Table 8 also exhibits the estimation results of unscheduled news related to the crisis in the case of pure news. Both US and EC unscheduled news trigger a decline in depth and slope during the recession but has a positively effect during the expansion. This asymmetrical effect was also observed in Table 7.

5.5 Asymmetric News Effects over Business Cycles

Table 9 presents the estimation results of equation (10). Aggregate good news has stronger effect on depth. Also, aggregated Good news have state-dependent effects on volatility, depth and quoted spread. However, in the case of slope, we have significant aggregated good news during recession and significant aggregated bad news during expansion. When aggregated good news or bad news happens, volatility, slope and depth increases, but quoted spread decreases. Compared coefficients of the two regimes, the characteristics tend to have a more intense response to the news during expansion.

US unscheduled news has an asymmetrical effect on volatility and depth during both regimes. US unscheduled news also has an asymmetrical effects on depth and spread, indicating that spread increases (decreases) during recession (expansion) respectively. EC unscheduled news is also asymmetric on slope depth and quoted spread. Depth tends to decrease during the recession but increase in the expansion. Slope tends to decrease during the recession and increase during the expansion when unscheduled news occurs.

6. Robustness Check

In this section, we perform robustness tests for the results presented in the above section. First, to check whether the proxy choice of method for different characteristics affects the empirical results, we summarize the measures of characteristics used in the literature. Basically, the proxies and their calculation methods for the LOB characteristics vary with the information extracted from the LOB. Second, we investigate the news effect on the ask side and bid side of the LOB. We utilize the methods of depth and slope in section 3 to investigate the effect of news surprise on the ask side and bid side of the LOB. Third, we examine the news effects on the different levels of the LOB. We perform the effects of news surprise on the volatility at the 2^{nd} to 5^{th} levels and the 5^{th} to 10^{th} levels in the book. And we perform the effects of news surprise on the depth and slope at the 2^{nd} to 5^{th} levels and the 5^{th} to 10^{th} levels on the ask side and bid side of the book.

In this section, we show alternative measures of characteristics for tick-by-tick data in section 6.1. Then we show the estimation results of the robustness check on the alternative methods for slope and volatility in section 6.2. Next, we perform the news effects on the LOB at the different sides (ask side and bid side) in section 6.3. Finally we show the news effects on the LOB at the different levels (the 2^{nd} to 5^{th} levels and the 5^{th} to 10^{th} levels) in section 6.4.

6.1 Alternative Measures of Characteristics

6.1.1 *Alternative Depth Method*

Instead of the depth measure we introduced in section 3.1.1, an alternative is widely applied in the literature which uses the term "depth" as the quantity of liquidity offered and demanded in the LOB (Nigmatullin, Tyurin and Yin, 2007; Gunther, W. 2008, Biais et al. 1995; Cao et al., 2004).

The LOB depth is the size which corresponds to the price of each level in every tick in LOB. In the literature, the depth for an interval *n* in the LOB is the sum of all the sizes for each tick at both sides. We compile the market depth based on the total number of limit orders posted at the bid and ask prices at the end of each time interval. So the size in every tick of an interval is calculated as: $Size_{n,i} = \sum_{l=1}^{L}[Q_{n,i,l}^{A}] + \sum_{l=1}^{L}[Q_{n,i,l}^{B}]$. So, the alternative method of "depth" is the overall size in a tick measures the amount of LOB liquidity. Compared to the depth used in the section 3, this alternative does not contain the prices. Following the same method introduced in section 3, we denote $Size_{t,n}$ as the time-weighted average of size in interval *n* at day *t*. Following the filter procedures in section 3.5, IAOM is applied to obtain the dummy which controls the seasonality pattern in a regression. Denote the seasonality dummy for size-weighted spread $Size_{t,n}$ as $AV_{t,n}^{Size}$ for interval *n* at day *t*. The intraday pattern of size is shown Figure 5.e, which has a similar tendency of intraday pattern to depth in Figure 1.a.

6.1.2 *Alternative Spread Method*

Usually, the spread of LOB refers to the price difference between the best quotes. For example, the quoted spread in section 3 is the percentage of the difference between the best quotes relative to the mid-price. Nevertheless, Kozhan and Salmon (2010) use size-weighted average prices at the ask side and bid side to get the size-weighted spread. Compared to the measures illustrated in section 3, Size-weighted spread combines all the prices and sizes for all LOB levels. Followed by the size-weighted prices of the ask and bid side in section 3.1.4, we denote the size-weighted spread in one tick i in an interval n as $wspread_{n,i}$: $wspread_{n,i} = AP^{A}_{n,i} - AP^{B}_{n,i}$. Following the same method introduced in section 3, we denote $wspread_{t,n}$ as the time-weighted average of size-weighted spread in interval *n* at day *t*. Following the filter procedures in section 3.5, we use IAOM to form a controlling dummy of the seasonality in regression, and denote the seasonality dummy for size-weighted spread $wspread_{t,n}$ as $AV^{wspread}_{t,n}$ for interval *n* at day *t*. The intraday pattern of size-weighted spread is shown Figure 5.c, which has a similar intraday pattern as the quoted spread in Figure 1.b.

6.1.3 *Alternative Slope Method*

Instead of the slope measure in Section 3, two alternative measures of slope are summarized from literature to investigate robustness of the results. Similar to the other characteristics, these slope measures differ based on the amount of LOB information. The three measures were implemented in two papers. “NORM SLOPE”,

the slope measure introduced by the Naes & Skjeltorp (2006), and "WSLOPE", the slope measure by Kozhan &Salmon (2010).

a. "NORM SLOPE"

With respect to the second alternative measure, we use "NORM SLOPE" by Naes & Skjeltorp (2006) where the slope of LOB is normalized to the total size at that tick. The difference of "NORM SLOPE" and the measure in Section 3.1.3 is that "NORM SLOPE" is the elasticity of size to price for the book. But the slope of the best quotes in Section 3 is measured based on the ratio of size to the percentage change of price. In other words, "NORM SLOPE" is the percentage size at each price level in one tick relative to the total size of all the price levels in that tick. Hence, the first and second terms here are measured in the same units in this method. In equation (12), NORM SLOPE standardizes the order book to the market cap and the corresponding liquidity in the LOB. Differing from the slope in Section 3, it can be used for comparisons among LOB levels (for example, the comparison between the slope of the best and the rest of the quotes). Define the percentage size of total size at each price level l in one tick i at ask side as $RQ^A_{n,i,l}$, so this percentage is calculated as: $RQ^A_{n,i,l} = \frac{Q^A_{n,i,l}}{\sum_1^L Q^A_{n,i,l}}$. The NORM SLOPE for the ask side on each tick i in interval n on date t is

$$Askslope^{NORM}_{n,i} = \frac{1}{L}\left[\frac{RQ^A_{n,i,1}}{\frac{P^A_{n,i,1}}{mid_{n,i}}-1} + \sum_{l=1}^{L-1}\left|\frac{\frac{RQ^A_{n,i,l+1}}{RQ^A_{n,i,l}}-1}{\frac{P^A_{n,i,l+1}}{P^A_{n,i,l}}-1}\right|\right], \quad (12)$$

similarly we get the NORM SLOPE for the ask side on each tick i in interval n on date t :$Bidslope^{NORM}_{n,i}$. The reason for taking the absolute value of the NORM SLOPE

for best quote is that we want to capture the magnitude of the elasticity. Finally, the "NORM SLOPE" for tick i in interval n at day t is: $slope_{t,n,i}^{NORM} = \left(Askslope_{t,n,i}^{NORM} + Bidslope_{t,n,i}^{NORM}\right) \times \frac{1}{2}$. So "NORM SLOPE" for a tick is the average of the NORM SLOPE of ask and bid side at that tick. Using the same method in section 3, the NORM SLOPE at interval n in day t is $slope_{t,n}^{NORM}$. We obtain the seasonality dummy of NORM SLOPE as $AV_{t,n}^{normslope}$ for interval *n* at day *t*. The intraday pattern of NORM SLOPE is shown Figure 5.a, which has a similar intraday pattern to in Figure 1.c.

b. WSLOPE

The slope measure used by Kozhan and Salmon (2010) only considers the best quotes and the second best quotes. We label this slope as "WSLOPE". The slope can be interpreted as the percentage of the difference of the best quote price to the second quote price relative to the best quote size. In other words, the difference of prices is normalized by the size of the best quote. Then we obtain the slope for the demand and supply curve. The WSLOPE of the ask side of the LOB at tick i is denoted as $e_{n,i}^{A}$[12]:

$$e_{n,i}^{A} = \frac{P_{n,i,1}^{A} - P_{n,i,2}^{A}}{Q_{n,i,1}^{A}}. \quad (13)$$

Similarly the WSLOPE of the bid side of the LOB at tick i is denoted as $e_{n,i}^{B}$.So the slope at tick i in interval n on day t is: $e_{t,n,i} = \left(e_{t,n,i}^{A} + e_{t,n,i}^{B}\right) \times \frac{1}{2}$. The slope by Kozhan and Salmon (2010) is the percentage of the change of prices between the best

[12]For the readability of the results, the price used in calculation of slope by Kozhan and Salmon is in the basis point. And the size is in the million.

and the second best relative to the size at the best quote. As an alternative slope measure, this slope is applied in the estimation in order to compare with other slopes that combine more information. We then follow the same method as in section 3 where the slope at interval n in day t is following: $e_{t,n}$ where $e_{t,n}$ is the time-weighted average of the slope in interval n in day t. Following the filter procedures in section 3.5, we use IAOM to form a dummy for controlling seasonality in the regression, and denote the seasonality dummy for slope by Kozhan and Salmon (2010) $e_{t,n}$ as $AV^{e}_{t,n}$ for interval *n* at day *t*.

6.1.4 *Alternative Method of Return*

The alternative measure of return is based on an alternative price. The alternative price is the average of the best ask price and the best bid price in every tick in the interval: $m_n = \frac{1}{2}(P^{A}_{n,\gamma_n} + P^{B}_{n,\gamma_n})$, where P^{A}_{n,γ_n} is the best ask price of the last tick γ_n in interval *n* and P^{B}_{n,γ_n} is the best bid price of the last tick γ_n in interval *n*. Then calculate the difference of the log-price of the last observation between the last and current interval to obtain the return. So the alternative method of return $r_{t,n}$ is: $r_{t,n} = (\log(m_{t,n+1}) - \log(m_{t,n})) \times 100$[13]. Here the volatility is a 5-min centered return, that is,$|r_{t,n} - \bar{r}|$ where $r_{t,n}$ is the return for interval *n* in day *t*, and $\bar{r}$ is the average return for $r_{t,n}$ of whole sample. Then we filter the volatility $|r_{t,n} - \bar{r}|$, denoted here as *Abs_ret*, by FFF following the procedures in section 3. Finally, we get the filtered volatility based on the best quote: $y_{t,n}$.

[13] Noting that the return calculated this way is very small, it is multiplied by 100 to give its percentage value.

6.2 Robustness Check of Characteristics

To describe the condition of LOB, we select four categories of LOB characteristics, which are "slope", "spread", "depth" and "volatility". Many alternative methods are introduced to compute the four categories of characteristics. We chose one method from each category to construct the VAR-STR model in the case of a news surprise. In Appendix A, an example is given to illustrate that the VAR model can be constructed based on all the alternative combinations of different characteristics.

To show the robustness of the slope, we compare the VAR-STR results of slope ($Slope_{t,n}$), NORM SLOPE ($slope_{t,n}^{NORM}$) and WSLOPE ($e_{t,n}$) with other characteristics unchanged ($Depth_{t,n}, Qspread_{t,n}, Volat_{t,n}$). Table 10 show the estimation results of the VAR-STR model for news surprise with three slope measures[14].

Slope is calculated the same as NORM SLOPE, except that NORM SLOPE is normalized by size. Slope and NORM SLOPE have similar total number of significant news in recession but NORM SLOPE has a larger response to news during expansion. The significant news in the estimation of slope and NORM SLOPE are distributed among EC, GE, IT and US. The news that have asymmetric state-dependent effects in the case of NORM SLOPE is much larger than that for slope. The reason may related to the calculation of NORM SLOPE which avoids the

[14] We eliminate the estimation results of the other three characteristics.

"different unit" problem in its calculation. News related to personal consumption and business indicator: preliminary and ISM manufacturing are both significant in the case of slope and NORMSLOPE

WSLOPE is calculated by using only the best and the second best quotes in the LOB, while slope is constructed based on all the information in the LOB. In Table 13, the significant estimation results of WSLOPE is inferior to slope as only 15% news are significant in WSLOPE while 25% are significant in slope. The results indicate that the news effect does exist no matter which method is chosen and that the slope which is calculated based on the whole book data is more informative. This is agrees with the empirical results in Cao et al. (2004), who shows that the LOB is more informative than the LOB's best quote.

To show the robustness of our volatility measures, we estimates the two methods of volatility ($voalt_{t,n}$ and $y_{t,n}$) with ($Depth_{t,n}, Qspread_{t,n}, Slope_{t,n}$) in the model VAR-STR with a news surprise. Table 11 presents the estimation results of the original volatility (section 3) and the alternative volatility introduced in section 6. The difference between methods is that the original volatility exploits all the information in LOB, while the alternative method use only the best quote. In Table 13, $y_{t,n}$ is only significant for 20% of news while the original volatility is 40%. Although the original volatility has a similar response during recession (24%) or expansion (21%), the alternative volatility $y_{t,n}$ has much stronger response to expansion (16%), relative to recession (6%). News related to housing market and employment are

both significant for both volatilities, such as housing starts, NAHB housing market index, and initial jobless claims. The results indicate that the news effect does exist no matter which method is been chosen; however, the original volatility is more informative than the alternative, implying the levels beyond the best quote are informative.

Overall, the robustness results for different measures of volatility and slope indicate that news effects on the LOB over regimes are robust to different measures of these proxies. In addition, the news effect is stronger when measures are constructed based on the whole book.

6.3 Robustness Check for News Effect on Ask and Bid Sides in LOB

In this section, we show the news effect on depth and slope for ask side and bid side in the LOB. The methods of depth and slope are introduced in section 3. Table 14 presents the news surprise effect on depth at the ask side and bid side in the LOB. In terms of the number of significant news announcements, news surprise has stronger effect on depth at both sides during the expansion. For example, in the ask side, 50 out of 89 news announcements are significant during the expansion but only 37 news announcements are significant during the recession. Also, nearly one-third news announcements have state-dependent effect or sign-switch effect at the ask side and the bid side. Table 15 presents the news surprise effect on slope at the ask side and the bid side of the LOB. In terms of the number of significant news announcements, news surprise has stronger effect on depth at the bid side. 15 out of 89 news announcements

are significant on the bid side but only 9 out of 89 news announcements are significant on the ask side. No news announcement has the state-dependent effect or sign-switch effect on slope for both sides. This result is the same as the estimation result of slope in Table 7.

In terms of the estimation coefficient, news surprise has similar effects on depth at the ask side and the bid side. For instance, in Table 14 Panel A, Household Cons QoQ – Preliminary has negative effect on depth during the recession, but it has positive effect on depth during the expansion for both sides in the LOB. And some news announcements, which have significant effect on depth of the whole book (Table 7), also have significant effect on depth at the ask side and the bid side, such as Consumer Confidence Index, Construction Spending MoM and Personal Spending. This result indicates that news surprise effect is robust to the different sides of the LOB.

6.4 Robustness Check for News Effect on different levels in LOB

To investigate the news effect on the different levels in the LOB, we estimate the news effect on volatility, depth and slope at the 2nd to 5th levels and the 5th to 10th levels in the book. We utilize the methods of volatility, depth and slope that we introduced in section 3. Table 16 shows the news surprise effect on volatility at the 2nd to 5th levels, the 5th to 10th levels of the book. News effect on the 2nd to 5th levels of the LOB is slightly inferior to that at the 5th to 10th levels: 32 out of 89 news announcements are significant at the 5th to 10th levels, and only 29 significant

news announcements at the 2nd to 5th levels. In terms of the estimation coefficients, new surprise has similar effects on volatility in the book. For example, Housing Starts has negative effect during the recession at both the 2nd to 5th levels and the 5th to 10th levels of the LOB.

Table 17 and Table 18 show the news surprise effect on depth or slope at the 2nd to 5th levels and the 5th to 10th levels at the ask side and the bid side of the book respectively. The number of significant news announcements at the 5th to 10th levels of the book is more than that at the 2nd to 5th levels, which indicates that the upper levels of the LOB are more sensitive to news surprise. In terms of the estimation coefficients, generally, the news effect is stronger on depth and slope at the upper levels in the book. For example, New Home Sales has larger negative effect on the 5th to 10th level for both recession and expansion. This result also verifies that the upper levels of the LOB have important information. Also, some news announcements, which have significant effect on depth for the whole book, also have significant effect on depth for the different levels, such as Existing Home Sales, NAHB Housing Market Index, and PPI Ex Food and Energy MoM. In sum, news surprise effect is robust to the different levels of the LOB.

7. Conclusion

We investigate the dynamics of LOB characteristics in FX ECN markets with respect to macroeconomic news between Jan. 3rd 2006 and Dec. 31st 2009, during which we the US crisis starts in 2008. We apply a VAR-STR model to macroeconomic news over different business regimes and find that the effect on characteristics not only vary with the type of news but also vary with the different business regimes.

We find that four characteristics are significantly influenced by news announcements but they can respond to economic cycles asymmetrically. Slope is more affected by both the news surprise and pure news during the recession; depth is more affected by pure news and the news surprise during the expansion. Quoted spread is more affected by the news surprise during expansion while has more intense responses to pure news to recession. News surprise has stronger effect on volatility during recession while pure news strongly affects volatility during expansion. Pure news announcements have stronger effects on characteristics, compared to news surprise. In addition, the LOB characteristics tend to have a more intense response to aggregated good or bad news during the expansion.

News announcements related to monetary policy, personal consumption, price index, forward looking, and employment significantly affect the four characteristics over different economic stages. Furthermore, news related to housing market, economic indicator consistently affects B characteristics. In addition, some news

announcements exhibit state-dependent effects as some of them have opposite LOB characteristics effects in two business regimes. Therefore, we find that news effect on LOB characteristics is affected by the context of the recent global crisis.

Our results show that news effects on LOB characteristics in different regimes is partially robust among different alternatives measures of these characteristics. The robustness check on depth and slope at ask side and bid side indicate that news announcements affect both sides of LOB symmetrically. Moreover, from the robustness check on different levels in the LOB, we find that upper levels in the LOB are more sensitive to news announcements that lower levels in the LOB.

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Tables

Table 1. Descriptive Statistics of LOB

	Mean	Median	Max	Min	Std. Dev.
Panel A: January 2006					
Number of Tick in an Interval at Ask Side	340	290	1134	1	233.25
Number of Tick in an Interval at Bid Side	340	289	1134	1	233.32
Number of Level in a Tick at Ask Side	9	9	22	1	2.18
Number of Level in a Tick at Bid Side	9	9	22	1	2.3
Size in the Best level at Ask Side	13,096,144	12,000,000	174,000,000	100,000	8,807,530
Size in the Best level at Bid Side	12,459,348	10,900,000	135,200,000	100,000	9,231,479
Sum Size of the LOB at Ask Side	75,900,682	76,400,000	238,200,000	1,000,000	26,762,696
Sum Size of the LOB at Bid Side	75,532,845	75,200,000	333,000,000	200,000	28,801,328
Spread	0.00018	0.00015	0.0049	0.00005	0.00014
Panel B: April 2009					
Number of Tick in an Interval at Ask Side	289	299	572	1	142.77
Number of Tick in an Interval at Bid Side	289	299	572	1	142.8
Number of Level in a Tick at Ask Side	23	23	45	1	5.18
Number of Level in a Tick at Bid Side	25	24	49	1	5.68
Size in the Best level at Ask Side	3,381,720	3,200,000	70,000,000	100,000	2,347,155
Size in the Best level at Bid Side	3,433,205	3,700,000	61,000,000	100,000	2,358,282
Sum Size of the LOB at Ask Side	66,115,081	67,100,000	132,750,000	500,000	13,815,915
Sum Size of the LOB at Bid Side	67,090,793	67,500,000	190,333,334	1,000,000	14,414,446
Spread	0.000157	0.00013	0.00363	0.00001	0.00009

Notes: Table 1 shows the descriptive statistics of the ask side and bid side of LOB in Jan. 2006 and Apr. 2009. Spread is the difference of the best ask price and the best bid price. Sum Size of the LOB at Ask side or Bid side is the accumulated size in all the levels in each tick.

Table 2. Summary Statistics of Characteristics of LOB

	Size	Depth	Abs_ret (%)	Abs_return (%)	QSpread	Sizespread	Slope	WSLOPE	NORMSLOPE
Mean	165,000,000	227,000,000	0.03	0.02	1.34	0.12	27,326.24	0.19	82,895.52
Median	157,000,000	214,000,000	0.02	0.01	1.11	0.08	23,614.00	0.13	52,259.76
Maximum	681,000,000	918,000,000	8.08	11.41	39.41	34.07	1,395,764	69.52	1,655,872
Minimum	700,000	1,908,834	0.00	0.00	0.07	0.00	1,883.37	0.00	102.94
Std. Dev.	80,918,569	116,000,000	0.04	0.06	1.75	0.16	19,956.18	0.47	84,406.19
Skewness	0.87	1.07	50.66	95.29	13.22	83.84	9.01	62.93	2.26
Kurtosis	4.84	5.28	9,855.75	13,145.47	216.25	14,386.11	291.98	6,588.99	11.24
N	245,780	245,780	245,780	245,780	245,780	245,780	245,780	245,780	245,780
AC(1)	0.973***	0.977***	0.24***	0.34***	0.949***	0.485***	0.762***	0.12***	0.88***
AC(2)	0.963***	0.968***	0.231***	0.119***	0.923***	0.418***	0.755***	0.085***	0.867***

Notes: Table 2 presents summary statistics of all the alternative methods of the depth, quoted spread, slope and volatility in 5-min frequency from 3rd Jan. 2006 to 31st Dec. 2009. Important to note is that characteristics in the Table 2 are not yet adjusted for intraday patterns. Quoted Spread, measured in basis points, is denoted as QSpread, which is the percentage of the price difference between the best bid price and the best ask price accounted for the mid-price of the LOB. Sizespread is difference of the size-weighted best ask price and the size-weighted best bid price. Depth is the sum of the product of size and price in each interval. Size is the sum of size in each interval. Slope measures the elasticity of the LOB supply and demand curve. NORM SLOPE is normalized slope. WSLOPE is the percentage of spread, measured in basis point, accounted for the size in the unit of million. *Abs_ret* is the absolute value of 5-min return. *Abs_return* is the absolute value of 5-min return which is calculated with size-weighted price. Both *Abs_ret* and *Abs_return* are presented in percentage. N is the observation number in the sample. AC (1) and AC (2) are the autocorrelation coefficients of characteristics with lag 1 and lag 2 respectively. The null is that no autocorrelation between characteristics and its lag orders. *** denotes the probability of insignificant figure is at 1% level.

Table 3. Summary Statistics of Characteristics in VAR-STR Model

	S_Size	S_Depth	S_QSpread	S_Sizespread	Volat (%)	Y (%)	S_NORMSLOPE	S_Slopw	S_WSLOPE
Mean	2.056	1.965	0.765	0.722	-0.335	-0.206	0.988	1.368	0.407
Median	1.952	1.860	0.632	0.507	0.058	0.365	0.623	1.181	0.271
Maximum	8.418	7.888	22.493	41.454	11.372	11.735	19.618	60.481	147.422
Minimum	0.009	0.016	0.040	0.006	-22.288	-12.173	0.001	0.094	0.000
Std. Dev.	1.000	1.000	1.000	1.000	2.43	2.815	1.000	1.000	1.000
Skewness	0.867	1.067	13.090	83.166	-1.158	-1.571	2.259	7.959	63.702
Kurtosis	4.848	5.292	211.178	14072.3	5.782	6.149	11.249	213.972	6647.47
N	245,780	245,780	245,780	245,780	245,780	245,780	245,780	245,780	245,780
AC(1)	0.973	0.977	0.949	0.485	0.088	0.085	0.88	0.762	0.762
AC(2)	0.963	0.968	0.923	0.418	0.071	0.06	0.857	0.755	0.755

Notes: Table 3 presents summary statistics of the characteristics used in estimation. The sample period is between 3rd Jan. 2006 to 31st Dec. 2009. Volat is the filtered absolute value of 5-min return which is calculated with size-weighted price. Y is filtered absolute value of 5-min return. Both Volat and Y are presented in percentage. S_size is the standardized size by dividing of 5-min size by Std. Dev. of 5-min size in the sample. S_depth is the standardized depth by dividing 5-min depth by Std. Dev. of 5-min depth in the sample. S_qspread is the standardized quoted spread by dividing 5-min quoted spread by Std. Dev. of 5-min quoted spread in the sample. S_sizespread is the standardized sizespread by dividing 5-min size-weighed spread by Std. Dev. of 5-min size-weighted spread in the sample. S_NORMSLOPE is the standardized NORM SLOPE by dividing 5-min NORMSLOPE by Std. Dev. of 5-min NORMSLOPE in the sample. S_WSLOPE is the standardized WSLOPE by dividing of 5-min WSLOPE by Std. Dev. of 5-min WSLOPE in the sample. N is the observation number in the sample. AC (1) and AC (2) are the autocorrelation coefficients of characteristics with lag 1 and lag 2 respectively. The null is that no autocorrelation between characteristics and their lag orders. *** denotes the probability of insignificant figure is at 1% level.

Table 4. Correlations between Characteristics in VAR-STR Model

	Y	Volat	S_SIZE	S_DEPTH	S_NORMSLOPE	S_QSPREAD	S_SIZESPREAD	S_SLOPE	S_WSLOPE
Y	-	-	-	-	-	-	-	-	-
Volat	0.590***	-	-	-	-	-	-	-	-
S_SIZE	-0.008***	-0.020***	-	-	-	-	-	-	-
S_DEPTH	-0.007***	-0.019***	0.988***	-	-	-	-	-	-
S_NORMSLOPE	0.003***	-0.002	0.551***	0.608***	-	-	-	-	-
S_QSPREAD	-0.043***	-0.016***	-0.093***	-0.096***	-0.101***	-	-	-	-
S_SIZESPREAD	0.015***	0.030***	-0.013***	-0.006***	-0.056***	0.067***	-	-	-
S_SLOPE	0.006***	0.008***	-0.214***	-0.203***	-0.126***	-0.190***	-0.192***	-	-
S_WSLOPE	0.010***	0.020***	-0.092***	-0.084***	0.001	0.085***	0.100***	-0.058***	-

Notes: Table 4 shows the correlation between the characteristics of liquidity and volatility variables used in the VAR-STR model. Volat is the filtered absolute value of 5-min return which is calculated with size-weighted price. Y is filtered absolute value of 5-min return. S_size is the standardized size by dividing of 5-min size by Std. Dev. of 5-min size in the sample. S_depth is the standardized depth by dividing 5-min depth by Std. Dev. of 5-min depth in the sample. S_qspread is the standardized quoted spread by dividing 5-min quoted spread by Std. Dev. of 5-min quoted spread in the sample. S_sizespread is the standardized sizespread by dividing 5-min size-weighed spread by Std. Dev. of 5-min size-weighted spread in the sample. S_NORMSLOPE is the standardized NORM SLOPE by dividing 5-min NORMSLOPE by Std. Dev. of 5-min NORMSLOPE in the sample. S_WSLOPE is the standardized WSLOPE by dividing of 5-min WSLOPE by Std. Dev. of 5-min WSLOPE in the sample. The null is that the correlation between any two characteristics are zero. *** denotes the probability of insignificant figure is at 1% level.

Table 5. News Announcement Filter

	Total		VAR-STR-Surprise				VAR-STR-Pure News			
Country	**Freq.**	**News**	**Freq.**	%	**News**	%	**Freq.**	%	**News**	%
EC	547	16	380	69%	15	94%	380	69%	14	88%
FR	132	3	113	86%	3	100%	113	86%	3	100%
GE	461	13	317	68%	13	100%	317	68%	10	77%
IT	240	8	197	82%	8	100%	197	82%	7	88%
PO	43	2	37	86%	2	100%	37	86%	2	100%
SP	132	4	99	75%	4	100%	99	75%	2	100%
US	1897	43	1156	61%	43	100%	1156	61%	36	84%
Total	**3452**	**89**	**2299**	**67%**	**88**	**100%**	**2299**	**67%**	**74**	**83%**

Notes: Table 5 shows the percentage of surprise and pure news after second round of data filtering. Country provide the countries' name corresponding to the news categories: EC- Euro Country, FR-France, GE-German, IT-Italy, PO-Poland, SP-Spain and US-United States. VAR-STR-Surprise shows the summary of filtered news for the STR model after the filter process in section 4.3.1. VAR-STR-Pure news shows the summary of filtered news for the STR model after the filter process in section 4.3.1. News and Freq. show the number of news categories and releases through entire sample period.

Table 6. Estimation Results of STR Model

ISM (EURUSD)						
γ	β	α	β'	α'	LSTR Type	c_k
4.111***	32.374	-0.17	201.598***	-0.396	LSTR1	0.496
(1.724)	(22.5)	(0.034)	(59.968)	(0.22)		(0.209)

Notes: Table 6 presents the parameter estimations in equation (6) and (7) by using ISM as transition variable. EUSUSD denotes for Euro/Dollar.β and β' are the coefficients of consolidated news in equation (6). ISM (Institute of Supply Management) is manufacturing index for US business cycles. The number in bracket are the standard errors. * denotes the probability of the figures which is not statistically significant at 10% level. *** denotes the probability of the figures which is not statistically significant at 1% level. LSTR Type is defined in equation (6). K=1 for LSTR1 model.

Table 7. Estimation Results of News Surprise

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone Macro News													
EC	Govt Expend QoQ - Preliminary	-3.965*	-	-	0.684***	-	-	-	-	-	-	-	-
EC	Gross Fix Cap QoQ - Preliminary	-	-	-	0.737***	0.276*	*0.63*	-	-	-	-	-	-
EC	Household Cons QoQ - Preliminary	-	-	-	-0.654***	0.249**	0.00	-	-	-	-	-	-
EC	Labour Costs YoY	-1.337*	4.308*	0.05	-	-0.535***	-	-	-	-	-	-	-
EC	Retail Sales MoM	-1.488**	-	-	-0.092*	-0.185***	0.1	-	-	-	-	-	-
EC	Trade Balance SA	-	-	-	-	0.294***	-	-	-	-	0.233*	-	-
EC	Business Climate Indicator	-	-	-	-	0.274***	-	-	-	-	0.21*	-	-
EC	CPI Core YoY – Final	-	-	-	-	-0.178***	-	0.155**	-	-	-0.271**	-	-
EC	GDP SA QoQ – Final	-	-	-	-	-0.205*	-	-	-	-	-	-	-
EC	Gross Fix Cap QoQ – Final	-	-	-	-	-0.443***	-	-	-	-	-	-	-
EC	Industrial New Orders SA (MoM)	-	-	-	-	0.207**	-	-	-	-	-	-	-
EC	Industrial Production SA MoM	-	-	-	-0.116*	-	-	-	-	-	-	-	-
EC	ZEW Survey Expectations	-	-	-	0.095**	-0.277***	0.00	-	-	-	0.276**	-	-
EC	CPI Estimate YoY	-	-	-	-0.102**	-	-	-0.135*	-	-	0.832***	-	-

Notes: Table 7 presents the estimation of scheduled and unscheduled macro news effect that over different regimes of business in our sample period, θ_q in equation (8). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. . Quoted Spread is denoted as QSpread, which is the percentage of the price difference between the best bid and the best ask price accounted for the mid-price of the LOB. Volat is the filtered absolute value of 5-min return which is calculated with size-weighted price. Depth is the sum of the product of size and price in each interval. Slope measures the elasticity of the LOB supply and demand curve.*, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 7. Estimation Results of News Surprise (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel B: US Macro News													
US	PPI Ex Food and Energy MoM	-	-1.605**	-	0.48***	-0.705***	0.00	-0.324***	-	-	-	-	-
US	ADP Employment Change	-	-3.459**	-	-	-1.691***	-	-0.619***	1.381***	0.00	-	-	-
US	PPI MoM	-	-	-	-0.2***	1.102***	0.00	-	-0.707***	-	-	-	-
US	Unemployment Rate	-	-	-	-0.143***	0.351***	0.00	-0.233***	-1.157***	0.00	0.194*	-	-
US	Empire Manufacturing	0.908*	-	-	0.253***	-	-	-	-	-	-0.226*	-	-
US	Existing Home Sales	1.277**	-	-	0.151***	0.866***	0.00	-	-	-	-	0.942***	-
US	Factory Orders	1.112***	-	-	-0.097***	-	-	-	-	-	-	-	-
US	FOMC Rate Decision	-	-	-	-	0.314***	-	-	-	-	0.151**	-	-
US	GDP Annualized QoQ - Advance	-	-3.673***	-	0.254***	-0.389***	0.00	-	-	-	-	-	-
US	GDP Annualized QoQ - Preliminary	-	-3.881**	-	0.412***	-0.92***	0.00	-	-	-	-	-	-
US	Housing Starts	-1.462***	-	-	-0.105**	0.42***	0.00	0.446***	-0.828***	0.00	-	-	-
US	Initial Jobless Claims	-	-	-	-	-	-	-0.188**	0.759***	0.00	-	-	-
US	ISM Non-Manf. Composite	1.58**	-6.649***	0.0	0.332***	-2.141***	0.00	-0.188**	-	-	0.3*	-	-
US	NAHB Housing Market Index	1.975***	-1.961***	0.0	-	-0.263***	-	-	-	-	-	-	-
US	Nonfarm Productivity - Final	1.39**	-3.725**	0.02	-	-0.622***	-	-	-	-	-	-	-
US	Nonfarm Productivity - Preliminary	1.542*	1.256*	*0.61*	0.463***	0.181***	*0.54*	-	-	-	-	-	-

Notes: Table 7 presents the estimation of scheduled and unscheduled macro news effect that over different regimes of business in our sample period, θ_q in equation (8). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 7. Estimation Results of News Surprise (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Avg Weekly Hours Production	-	-	-	-0.234***	-	-	0.27***	-	-	-	-0.771***	-
US	Business Inventories	-	-	-	-0.129***	0.405***	0.00	-	-	-	-	-	-
US	Chicago Purchasing Manager	-	-	-	-0.088*	0.716***	0.00	-	-	-	-	-	-
US	Construction Spending MoM	-	-	-	0.218***	0.659***	0.00	-	-	-	-	-	-
US	Consumer Confidence Index	-0.688*	-	-	0.071**	0.517***	0.00	-	-1.488***	-	-	-	-
US	Core PCE QoQ - Advance	-	-8.989**	-	0.348***	-1.275***	0.00	-1.002***	1.7***	0.00	-	-	-
US	Core PCE QoQ - Preliminary	-	-	-	-	-2.393***	-	0.618***	1.452***	0.00	-0.631***	-	-
US	CPI Ex Food and Energy MoM	-	-	-	-0.071*	0.331***	0.00	-	-	-	-	-	-
US	Import Price Index MoM	-	-	-	-	0.478***	-	-	-	-	-	-	-
US	Industrial Production MoM	-	-	-	-	0.39***	-	0.147***	0.259*	0.25	-	-	-
US	ISM Manufacturing	-	-	-	-0.081*	0.426***	0.00	0.222***	-0.295***	0.00	0.273**	-	-
US	ISM Milwaukee	-	-	-	-	1.025***	-	-	-	-	-	-	-
US	Retail Sales Ex Auto MoM	-	-	-	-		-	0.305***	0.515***	0.00	-	-	-
US	Trade Balance	0.858*	-	-	0.2***	-0.286***	0.00	-0.108*	-	-	-	-	-
US	Personal Spending	-	-	-	0.182***	0.383***	0.00	-	-0.426***	-	-	-	-
US	Philadelphia Fed Business Outlook	-	-	-	-0.095**	0.389***	0.00	-	-	-	-	-	-
US	Avg Hourly Earning MOM Prod	-	-	-	-	-	-	0.211**	-	-	-	-	-
US	Change in Nonfarm Payrolls	-	-3.677***	-	-	-	-	0.132**	1.431***	0.00	-	-0.52**	-
US	Durables Ex Transportation	-	-	-	-0.073***	-0.261***	0.00	-	-	-	0.206***	-	-

Notes: Table 7 presents the estimation of scheduled and unscheduled macro news effect that over different regimes of business in our sample period, θ_q in equation (8). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain.*, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 7. Estimation Results of News Surprise (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Univ. of Michigan Confidence - Preliminary	-	-	-	-	0.189***	-	0.11*	-	-	-0.293***	-	-
US	Wholesale Inventories MoM	-	-	-	-	0.862***	-	-0.14**	-	-	-	-	-
US	Net Long-term TIC Flows	-	-	-	-0.167***	-	-	0.597***	0.591***	0.03	-	-	-
US	New Home Sales	-	-	-	-0.458***	-	-	0.342***	-	-	-	-	-
US	PCE Core MoM	-	-2.244***	-	-0.717***	-	-	0.197**	1.484***	0.00	-	-	-
US	Personal Consumption - Preliminary	-	-	-	-0.293***	-	-	-	-1.051***	-	0.538*	-	-
US	Pending Home Sales MoM	-	-	-	0.419***	-	-	0.928/***	-	-	-	-	-
Panel C: European Countries													
GE	IFO Business Climate	-	1.799**	-	0.352***	-	-	-0.187**	-	-	-	-	-
GE	Imports QoQ	-	-	-	-0.168*	-	-	-	-	-	-	-	-
GE	Industrial Production SA MoM – Preliminary	-	-	-	-	-0.386***	-	-	-	-	-	-	-
GE	Private Consumption QoQ	-	-	-	0.2288**	-	-	-	-	-	-	-	-
GE	Retail Sales MoM	-1.282**	-	-	-0.082*	-	-	-	-	-	-0.359**	-	-
GE	ZEW Survey Current Situation	-	-4.116**	-	-	0.345**	-	-	-	-	0.277**	-	-
GE	Exports QoQ	-	-	0.137*	-	-	-	-	-	-	-	-	-
GE	ZEW Survey Expectations	-	-	-	-	-	-	-	-	-	-0.607***	-	-
GE	Factory Orders WDA YoY - Preliminary	-	1.268*	-	-	-	-	-	-	-	-	-	-

Notes: Table 7 presents the estimation of scheduled and unscheduled macro news effect that over different regimes of business in our sample period, θ_q in equation (8). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain.*, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 7. Estimation Results of News Surprise (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
GE	Unemployment Rate	-	-	-	-	-	-	-	-	-	0.194*	-	-
GE	Construction Investment QoQ	-	-	-	-	-	-	-	-	-	-	-	-
GE	PPI MoM	-	-	-	-	-	-	0.182***	0.293*	*0.17*	-	-	-
IT	Business Confidence	-	-1.426*	-	-	-0.143**	-	-0.259**	-	-	-0.259**	-	-
IT	GDP WDA QoQ - Preliminary	-	-	-	-	-0.519***	-	-	-	-	-	-	-
IT	Retail Sales MoM	-	-	-	-	-0.183**	-	-0.155**	-	-	-	-	-
IT	Total investments	-	-	-	-	0.398**	-	-	-	-	-	-	-
IT	Trade Balance Total	-	-1.657*	-	-0.102*	-	-	-	-	-	-	-	-
SP	CPI MoM	-	-1.387**	-	-	-0.159*	-	-	-	-	-	-	-
SP	Retail Sales WDA YoY	-	4.676**	-	-	-	-	-	-	-	-	-	-
PO	CPI MoM	-	-	-	-	-	-	0.593**	-	-	-	-	-
Panel D: Unscheduled News													
US	Unscheduled News	0.05***	-0.131***	0.01	-0.007***	0.044***	0.00	0.015***	-0.041***	0.00	-0.109***	0.088***	0.00
EC	Unscheduled News	-	0.204**	-	-0.017***	0.038***	0.00	0.017***	-0.026**	0.00	-0.143***	0.098***	0.00

Notes: Table 7 presents the estimation of scheduled and unscheduled macro news effect that over different regimes of business in our sample period, θ_q in equation (8). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain.*, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ'_q in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 8. Estimation Results of Pure News

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone Macro News													
EC	Business Climate Indicator	-	-	-	0.222***	0.19**	0.04	-	-	-	-0.434***	-	-
EC	CPI Core YoY - Final	1.833***	-	-	0.308***	0.47***	0.00	-0.244**	-	-	0.849***	-	-
EC	CPI Estimate YoY	-	-	-	0.32***	0.219**	*0.52*	-0.238**	-	-	-	-	-
EC	ECB Announces Interest Rates	1.932***	1.621**	*0.37*	0.775***	1.357***	0.00	-0.919***	-0.743***	0.02	0.33**	-	-
EC	Govt Expend QoQ - Preliminary	-	-	-	0.268***	0.557***	0.00	-	-	-	-	-	-
EC	Industrial New Orders SA (MoM)	-	-	-	0.127***	0.187***	*0.12*	-	-	-	-	-	-
EC	Industrial Production SA MoM	-	-	-	0.215***	0.236***	*0.12*	-	-	-	-	-	-
EC	Labour Costs YoY	-	-	-	-	0.648***	-	-	-	-	-	-	-
EC	PMI Manufacturing - Preliminary	1.21*	-	-	-	0.553***	-	-	-	-	-	-	-
EC	Retail Sales MoM	1.666***	-	-	0.146***	0.527***	0.00	-0.13*	-	-	-	-	-
EC	Trade Balance SA	-	-	-	0.115**	0.472***	0.00	-0.19***	-	-	-	-	-
EC	ZEW Survey Expectations	-	-	-	-	0.191**	-	-	-	-	-	-	-
Panel B: US Macro News													
US	ADP Employment Change	3.332***	1.956**	*0.85*	0.796***	1.763***	0.00	-0.493***	-0.55***	0.05	-	-	-
US	Avg Hourly Earning MOM Prod	4.445***	5.528***	0.00	0.438***	0.886***	0.00	-1.739***	-2.769***	0.00	0.297**	0.894***	0.00
US	Construction Spending MoM	-	-	-	0.281***	0.718***	0.00	-	-0.999***	-	-	-	-
US	Consumer Confidence Index	1.757***	-	-	0.617***	1.000***	0.00	-0.985***	-0.371***	0.02	-	-	-
US	Core PCE QoQ - Preliminary	2.243***	-	-	0.456***	1.134***	0.00	-0.571***	-0.812***	0.00	0.569**	-	-

Notes: Table 8 presents estimation results of the selected pure news effect and unscheduled news effect over different regimes of business in our sample period, ξ_q in equation (9). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of ξ_q' in equation (9), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession

Table 8. Estimation Results of Pure News (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	ISM Milwaukee	-	-	-	0.202**	1.462***	0.00	-	-	-	-	-	-
US	ISM Non-Manf. Composite	-	3.952**	-	0.462***	3.11***	0.00	-0.915***	-	-	-	-	-
US	NAHB Housing Market Index	-	1.529**	-	0.325***	0.378***	0.00	-	-	-	-	-	-
US	New Home Sales	-	4.012***	-	0.628***	1.355***	0.00	-1.285***	-1.01***	0.00	-	0.453**	-
US	Nonfarm Productivity - Final	-	-	-	0.278***	0.87***	0.00	-0.253*	-0.308*	*0.4*	-	-	-
US	Empire Manufacturing	-	-	-	0.466***	0.801***	0.00	-0.467***	-0.317***	*0.51*	-	-	-
US	Existing Home Sales	1.606***	2.119***	0.00	0.492***	1.153***	0.00	-	-	-	-	-	-
US	Factory Orders	0.947***	1.721***	0.00	0.545***	1.147***	0.00	-0.196***	-0.452***	0.00	-	-	-
US	FOMC Rate Decision	5.078***	4.782***	0.07	0.244***	0.873***	0.00	-1.977***	-1.334***	0.01	-	-	-
US	GDP Annualized QoQ - Advance	5.25**	4.343*	*0.67*	1.083***	0.968***	*0.12*	-2.544***	-0.986**	*0.55*	-	-	-
US	Housing Starts	1.105*	1.797*	0.05	0.333***	0.836***	0.00	-	-0.316**	-	-	-	-
US	IBD/TIPP Economic Optimism	-	-	-	-	0.302***	-	-	-	-	-	-	-
US	Import Price Index MoM	-	-	-	-	0.506***	-	-	-0.362***	-	-	-	-
US	Industrial Production MoM	-	-	-	0.852***	1.292***	0.00	-0.464***	-0.297***	*0.63*	-	-	-
US	Initial Jobless Claims	-	-	-	0.451***	0.963***	0.00	-0.501***	-0.498***	0.00	-	-	-
US	Business Inventories	-	-	-	0.596***	0.697***	0.00	-0.156**	-	-	-	-	-
US	Chicago Purchasing Manager	-	-	-	0.517***	0.969***	0.00	-	-	-	0.309**	-0.33*	0.03
US	Net Long-term TIC Flows	1.365**	2.905***	0.02	0.73***	1.391***	0.00	-1.039***	-0.484***	*0.82*	0.232*	-	-
US	ISM Manufacturing	-	-	-	0.584***	0.407***	0.03	-0.762***	0.446**	0.00	-	-	-

Notes: Table 8 presents estimation results of the selected pure news effect and unscheduled news effect over different regimes of business in our sample period, ξ_q in equation (9). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of ξ_q' in equation (9), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession

Table 8. Estimation Results of Pure News (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Nonfarm Productivity - Preliminary	2.361**	-	-	0.614***	0.265***	0.00	-0.619***	-	-	-	-	-
US	PCE Core MoM	-	2.69***	-	0.477***	1.427***	0.00	-0.725***	-1.285***	-	-	-	-
US	Core PCE QoQ - Advance	-	-	-	-0.541**	-	-	2.044***	-	-	-	-	-
US	Pending Home Sales MoM	-	-	-	0.571***	0.531***	0.00	0.269***	-	-	-	-	-
US	Philadelphia Fed Business Outlook	-	2.265***	-	0.605***	1.508***	0.00	-0.804***	-0.213***	*0.1*	-	-	-
US	PPI Ex Food and Energy MoM	-	-	-	0.304***	1.305***	*0.00*	-1.322***	-0.372***	0.03	-	-	-
US	Retail Sales Ex Auto MoM	2.254***	2.089**	0.03	0.309***	0.918***	0.00	-0.897***	-1.061***	0.00	-	-	-
US	Trade Balance	1.143**	2.76***	0.05	0.87***	0.803***	0.00	-1.312***	-1.048***	0.00	0.292*	-	-
US	Univ. Michigan Confidence - Preliminary	1.1**	1.559**	*0.29*	0.214***	0.573***	0.00	-0.368***	-0.315***	*0.23*	-	-	-
US	Wholesale Inventories MoM	-	1.42*	-	0.44***	0.632***	0.00	-0.183**	-	-	-	-	-
US	CPI Ex Food and Energy MoM	2.134***	-	-	0.547***	0.905***	0.00	-1.736***	-1.161***	0.03	-	-	-
US	Durables Ex Transportation	1.792***	2.366***	*0.16*	0.568***	0.825***	0.00	-1.04***	-1.084***	0.00	-	-	-
Panel C: European Countries Macro News													
GE	Construction Investment QoQ	-	-	-	-	0.168*	-	-	-	-	-	-	-
GE	Factory Orders WDA YoY - Preliminary	1.598***	-	-	-	0.219***	-	-	-	-	-	-	-
GE	GDP SA QoQ - Preliminary	2.292***	-	-	-	0.277***	-	-	-	-	-	-	-
GE	IFO Business Climate	2.467***	2.864***	0.06	0.436***	0.687***	0.00	-0.214***	-0.285***	0.1	-	-	-
GE	PPI MoM	1.152**	-	-	0.11**	0.232***	0.03	-	-	-	-	-	-
GE	Retail Sales MoM	1.15**	-	-	-	0.226***	-	-0.144**	-	-	-	-	-

Notes: Table 8 presents estimation results of the selected pure news effect and unscheduled news effect over different regimes of business in our sample period, ξ_q in equation (9). CN presents the corresponding country name of the news: EC - Euro Zone Aggregate; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of ξ_q' in equation (9), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession

Table 8. Estimation Results of Pure News (continued)

		VOLAT			DEPTH			QSPREAD			SLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
GE	Industrial Production SA MoM Preliminary	1.233**	-	-	0.18***	0.408***	0.00	-	-	-	-	-	-
GE	Unemployment Rate	-	-	-	-0.103**	-	-	-	-	-	-	-	-
GE	ZEW Survey Expectations	-	-	-	-	-1.095**	-	-1.367*	-	-	-	-	-
GE	ZEW Survey Current Situation	-	-	-	-	1.756***	-	-	-	-	-	-	-
FR	PPI MoM	-	-	-	-	-	-	0.147*	-	-	-	-	-
SP	CPI EU Harmonised YoY - Final	-	-	-	0.154***	-0.159**	0.01	-	-	-	-	-	-
PO	GDP YoY - Final	-	-	-	-	-	-	-	-	-	-	1.111**	-
PO	CPI MoM	-	-	-	-	0.186**	-	-0.234***	-	-	-	-	-
IT	Business Confidence	-	-	-	0.105**	0.206***	0.04	-	-	-	-0.385***	-	-
IT	GDP WDA QoQ - Preliminary	-	-	-	-	0.315**	-	-	-	-	-	-	-
IT	Industrial Production WDA YoY	-	-	-	0.185***	0.136**	*0.64*	-	-	-	-	-	-
IT	Retail Sales MoM	-	-	-	0.099**	0.244***	0.02	-	-	-	-	-	-
IT	Trade Balance Total	-	-	-	0.108**	0.172**	*0.21*	-	-	-	-	-	-
Panel D: Unscheduled News													
US	Unscheduled News	0.054***	-0.152***	0.00	-0.005***	0.035***	0.00	0.013***	-0.032***	0.00	-0.109***	0.086***	0.00
EC	Unscheduled News	-	0.188**	-	-0.014***	0.025***	0.00	0.014***	-0.019*	0.02	-0.143***	0.098***	0.00

Notes: Table 8 presents estimation results of the selected pure news effect and unscheduled news effect over different regimes of business in our sample period, ξ_q in equation (9). CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of ξ_q' in equation (9), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession

Table 9. Estimation Results of Good and Bad News

	VOLAT			DEPTH			QSPREAD			SLOPE		
	Recession	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Aggregated Good	1.168***	1.188***	0.00	0.374***	0.744***	0.00	-0.421***	-0.354***	0.00	0.103***	-	-
Aggregated Bad	0.879***	1.218***	0.00	0.329***	0.714***	0.00	-0.408***	-0.42***	0.00	-	0.098**	-
US unscheduled	0.054***	-0.145***	0.00	-0.006***	0.038***	0.00	0.013***	-0.035***	0.00	-0.109***	0.087***	0.00
EC unscheduled	-	0.194**	-	0.014***	0.03***	0.00	0.015***	-0.021**	0.01	-0.142***	0.098***	0.00

Notes: Table 9 presents the estimation results of aggregated good and bad news effect and unscheduled news effect in different regimes in equation ρ_g and ρ_b (10). *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. Quoted Spread is denoted as QSpread, which is the percentage of the price difference between the best bid and the best ask price accounted for the mid-price of the LOB. Volat is the filtered absolute value of 5-min return which is calculated with size-weighted price. Depth is the sum of the product of size and price in each interval. Slope measures the elasticity of the LOB supply and demand curve. P_diff presents the P value of ρ'_g and ρ'_b in equation (10), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 10. Robustness Results of Surprise on Alternative Slopes

		SLOPE			NORMSLOPE			WSLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone Macro News										
EC	Labour Costs YoY	-	-	-	-	1.02**	-	-	-	-
EC	Retail Sales MoM	-	-	-	-	-0.649***	-	-	-	-
EC	CPI Core YoY - Final	-0.271**	-	-	-	-	-	-	-	-
EC	CPI Estimate YoY	0.832***	-	-	-	-	-	-	-	-
EC	Business Climate Indicator	0.21*	-	-	-	-	-	-	-	-
EC	Trade Balance SA	0.233**	-	-	-	-	-	-	-	-
EC	ZEW Survey Expectations	0.276**	-	-	0.176*	-0.317*	*0.92*	-	-	-
Panel B: US Macro News										
US	Avg Weekly Hours Production	-	-0.771***	-	-0.304***	-	-	-	-0.876**	-
US	Business Inventories	-	-	-	-0.274***	0.325**	*0.88*	-	-	-
US	Chicago Purchasing Manager	-	-	-	-	0.32**	-	-	-	-
US	Construction Spending MoM	-	-	-	0.188*	0.391*	*0.72*	-	-	-
US	Core PCE QoQ - Preliminary	-0.631***	-	-	-	-1.326***	-	-0.705*	-	-
US	CPI Ex Food and Energy MoM	-	-	-	-	0.515**	-	-0.401**	-	-
US	Factory Orders	-	-	-	-	-0.27*	-	-	-	-
US	GDP Annualized QoQ - Preliminary	-	-	-	0.572**	-0.939***	0.02	-	-	-
US	Import Price Index MoM	-	-	-	0.214**	-	-	-	-	-
US	Initial Jobless Claims	-	-	-	-	-0.319***	-	-	-	-

Notes: Table 10 presents the estimation results of significant scheduled and unscheduled news effect on slope, NORMSLOPE and WSLOPE. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 10. Robustness Results of Surprise on Alternative Slopes (continued)

		SLOPE			NORMSLOPE			WSLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Nonfarm Productivity - Preliminary	-	-	-	0.466***	0.389***	*0.62*	-	-	-
US	PCE Core MoM	-	-	-		-0.59***	-	-	-	-
US	Personal Consumption - Preliminary	0.538*	-	-	-0.465**	0.705**	0.03	-	-	-
US	Personal Spending	-	-	-		0.638***	-	-	-	-
US	PPI Ex Food and Energy MoM	-	-	-	0.207*	-0.319**	0.06	-	-	-
US	Retail Sales Ex Auto MoM	-	-	-	0.177**	0.262*	*0.44*	0.294*	-	-
US	Durables Ex Transportation	0.206*	-	-	-	-	-	-	-	-
US	Existing Home Sales	-	0.942***	-	-	-	-	-	-	-
US	FOMC Rate Decision	-	-	-	-	0.253**	-	-0.772***	0.507*	*0.82*
US	Unemployment Rate	0.561***	-	-	-	-	-	-	-	-
US	Change in Nonfarm Payrolls	-	-0.52**	-	-	-	-	-	2.212***	-
US	Univ. Michigan Confidence Preliminary	-0.293**	-	-	-	-	-	-	-	-
US	GDP Annualized QoQ - Advance	-	-	-	-	-	-	-0.747*	-	-
US	ADP Employment Change	-	-	-	-	-	-	-	-	-
US	ISM Manufacturing	0.273**	-	-	-	0.369***	-	-	-	-
US	ISM Milwaukee	-	-	-	-	0.797**	-	-	-	-
US	ISM Non-Manf. Composite	0.3**	-	-	0.212*	-2.028***	0.00	-	-	-

Notes: Table 10 presents the estimation results of significant scheduled and unscheduled news effect on slope, NORMSLOPE and WSLOPE. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 10. Robustness Results of Surprise on Alternative Slopes (continued)

		SLOPE			NORMSLOPE			WSLOPE		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel C: European Countries Macro News										
GE	IFO Business Climate	-	-	-	-	-	-	-	0.971***	-
GE	PPI MoM	-	-	-	-0.19***	-	-	-	-	-
GE	Retail Sales MoM	-0.359**	-	-	0.191*	-0.33**	*0.27*	-	-	-
GE	Unemployment Rate	0.194*	-	-	-	-	-	-	-	-
GE	ZEW Survey Current Situation	0.277**	-	-	-	-	-	-	-	-
GE	ZEW Survey Expectations	-0.607**	-	-	-	-	-	-	-	-
IT	Business Confidence	-0.259**	-	-	-	-	-	-	-	-
CN	**Unscheduled News**									
US	Unscheduled News	-0.109***	0.088***	0.00	0.038***	0.148***	0.00	0.118***	0.072***	0.00
EC	Unscheduled News	-0.143***	0.098***	0.00	-0.018***	-	-	-	-	-

Notes: Table 10 presents the estimation results of significant scheduled and unscheduled news effect on slope, NORMSLOPE and WSLOPE. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 11. Robustness Results of Surprise on Alternative Volatilities

		VOLAT			Y		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone Macro News							
EC	Govt Expend QoQ - Preliminary	-3.965*	-	-	-	-	-
EC	Labour Costs YoY	-1.337*	4.308*	0.05	-	6.76**	-
EC	Retail Sales MoM	-1.488**	-	-	-	-	-
Panel B: US Macro News							
US	ADP Employment Change	-	-3.459**	-	-	-	-
US	Change in Nonfarm Payrolls	-	-3.677***	-	-	-3.165***	-
US	Consumer Confidence Index	-0.688*	-	-	-	-	-
US	Empire Manufacturing	0.908*	-	-	-	-	-
US	Factory Orders	1.112**	-	-	-	-	-
US	FOMC Rate Decision	0.775**	-	-	-	1.671**	-
US	GDP Annualized QoQ - Advance	-	-3.673***	-	-	-4.041***	-
US	GDP Annualized QoQ – Preliminary	-	-3.881***	-	-	-3.641*	-
US	Housing Starts	-1.462***	-	-	-	-	-
US	Initial Jobless Claims	-	-1.294***	-	-	-1.83***	-
US	ISM Non-Manf. Composite	1.58**	-6.649***	0.00	-	-	-
US	NAHB Housing Market Index	1.975***	-1.961***	0.00	-	-1.616**	-
US	Nonfarm Productivity - Final	1.39**	-3.725**	0.02	1.93**	-	-
US	Nonfarm Productivity - Preliminary	1.542*	1.256*	*0.61*	-	-	-
US	PCE Core MoM	-	-2.224***	-	-	-2.1**	-
US	Personal Consumption - Preliminary	-	-	-	-2.276*	-	-
US	PPI Ex Food and Energy MoM	-	-1.605**	-	-	-	-
US	Trade Balance	0.858*	-	-	1.091**	-	-
US	Import Price Index MoM	-	-	-	-0.888*	2.191**	0.01
US	Core PCE QoQ - Advance	-	-8.989**	-	-	-4.516*	-

Notes: Table 11 presents the estimation results of surprise of the selected significant scheduled and unscheduled macro news effect of two alternatives of volatility. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 11. Robustness Results of Surprise on Alternative Volatilities (continued)

		VOLAT			Y		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel C: European Countries Macro News							
GE	Retail Sales MoM	-1.282**	-	-	-	-	-
GE	ZEW Survey Expectations	-	-4.115**	-	-	-	-
GE	Factory Orders WDA YoY - Preliminary	-	1.268*	-	-	-	-
GE	IFO Business Climate	-	1.779**	-	-	2.056***	-
SP	CPI MoM	-	-1.387**	-	-	-1.405**	-
SP	Retail Sales WDA YoY	-	4.676**	-	-	5.143**	-
IT	Business Confidence	-	-1.426*	-	-	-	-
IT	Trade Balance Total	-	-1.657*	-	-	-	-
IT	Retail Sales MoM	-	-	-	-	-1.712**	-
CN	**Uncheduled News**						
US	Unscheduled News	0.05***	-0.131***	0.02	0.097***	-	-
EC	Unscheduled News	-	0.204**	-	0.124**	0.191**	0.00

Notes: Table 11 presents the estimation results of surprise of the selected significant scheduled and unscheduled macro news effect of two alternatives of volatility. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the P value of θ_q' in equation (8), which is the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 12. Number of Significant News

		VOLAT			DEPTH			QSPREAD			SLOPE		
Country	**Total**	**Recession**	**Expansion**	**SD**	**Recession**	**Expansion**	**SD**	**Recession**	**Expansion**	**SD**	**Recession**	**Expansion**	**SD**
Panel A: Surprise													
EC	16	3	1	1	7	11	2	7	11	0	5	0	0
FR	3	0	0	0	0	0	0	0	0	0	0	0	0
GE	13	1	3	0	4	3	0	4	4	0	4	0	0
IT	8	0	2	0	1	4	0	1	4	0	1	0	0
PO	2	0	0	0	0	0	0	0	0	0	0	0	0
SP	4	0	2	0	0	1	0	1	0	0	0	0	0
US	43	11	12	2	28	32	19	28	34	12	9	3	0
Total	**89**	**15 (17%)**	**19 (21%)**	**3 (3%)**	**40 (45%)**	**51 (57%)**	**21 (24%)**	**41 (46%)**	**53 (60%)**	**12 (13%)**	**19 (21%)**	**3 (3%)**	**0 (0%)**
Panel B: Pure News													
EC	14	4	1	0	9	12	6	5	1	1	3	0	0
FR	3	0	0	0	1	1	0	1	0	0	0	0	0
GE	10	6	1	1	4	9	3	1	1	0	0	0	0
IT	7	0	0	0	4	5	1	0	0	0	1	0	0
PO	2	0	0	0	0	0	0	1	0	0	0	1	0
SP	2	0	0	0	1	1	1	0	0	0	0	0	0
US	36	17	19	8	34	35	32	29	25	14	5	4	2
Total	**74**	**27 (30%)**	**21 (24%)**	**9 (10%)**	**53 (60%)**	**63 (71%)**	**42 (47%)**	**37 (42%)**	**27 (30%)**	**15 (17%)**	**9 (10%)**	**5 (6%)**	**2 (2%)**

Notes: Table 12 shows the percentage of significant news in each country for estimation results of VAR-STR with news surprise and pure news. Country provide the countries name corresponding to the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. Panel A and B contains the significant and state-dependent news information surprise and pure news respectively. The content in the table, that is, **(%)** stands for the percentage of the number of significant dependent news in regression and expansion. Total is the sum of significant news of each characteristics in two regimes.SD stands for the number of state dependent news.

Table 13. Number of Significant News in Robustness

		EC	FR	GE	IT	PO	SP	US	Total
Robustness Check of Alternative Slopes									
SLOPE	**Recession**	5	0	4	1	0	0	9	**19 (21%)**
	Expansion	0	0	0	0	0	0	3	**3 (3%)**
	Sum	**5**	**0**	**4**	**1**	**0**	**0**	**12**	**22 (25%)**
NORMSLOPE	**Recession**	1	0	1	1	0	0	11	**14 (16%)**
	Expansion	3	0	0	1	0	0	20	**24 (27%)**
	Sum	**4**	**0**	**1**	**2**	**0**	**0**	**31**	**39 (44%)**
WSLOPE	**Recession**	0	0	0	1	1	0	6	**8 (9%)**
	Expansion	0	0	1	0	0	0	4	**5 (6%)**
	Sum	**0**	**0**	**1**	**1**	**1**	**0**	**10**	**13 (15%)**
Robustness Check of Alternative Volatilities									
VOLAT	**Recession**	3	0	1	0	0	0	11	**15 (17%)**
	Expansion	1	0	3	2	0	2	12	**20 (22%)**
	Sum	**4**	**0**	**4**	**5**	**0**	**5**	**23**	**41 (46%)**
Y	**Recession**	5	0	4	1	0	0	9	**19 (21%)**
	Expansion	0	0	0	0	0	0	3	**3 (3%)**
	Sum	**5**	**0**	**4**	**1**	**0**	**0**	**12**	**22(25%)**
	N	**16**	**3**	**13**	**8**	**2**	**4**	**43**	**89**

Notes: Table 13 shows the percentage of significant news surprise category in each country of alternative methods of slope and volatility. Country provide the countries name corresponding to the news: EC- Euro Zone, FR-France, GE-German, IT-Italy, PO-Poland, SP-Spain, and US-United States. Panel A is the significant news information of three slope measures. Panel B is the significant news information of two return volatility measures. The content in the table, that is, (%) stands for the percentage of the number of significant dependent news in regression and expansion. N is the total of news category in each country. Sum in every section of characteristic is the sum of significant news regardless regime. Total is the sum of significant news of each characteristics in two regimes.

Table 14. Robustness Results of Surprise on Depth at Ask and Bid Sides

Depth		**Ask Side**			**Bid Side**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone News							
EC	Business Climate Indicator	-	0.284***	-	-	0.277***	-
EC	CPI Core YoY - Final	-	-0.243***	-	-0.097*	-	-
EC	CPI Estimate YoY	-0.095*	0.214*	*0.55*	-	-	-
EC	GDP SA QoQ - Final	-	-0.249**	-	-	-	-
EC	Govt Expend QoQ - Preliminary	0.634***	-	-	0.688***	-	-
EC	Gross Fix Cap QoQ - Final	-	-0.533***	-	0.229**	-	-
EC	Gross Fix Cap QoQ - Preliminary	0.656***	0.367**	*0.3*	0.719***	-	-
EC	Household Cons QoQ - Preliminary	-0.611***	0.346***	0.01	-0.648***	0.206*	0.00
EC	Labour Costs YoY	-	-0.551**	-	-	-0.420*	-
EC	Retail Sales MoM	-0.093*	-	-	-	-0.216***	-
EC	Trade Balance SA	-0.087*	0.288***	0.04	-	0.242***	-
EC	ZEW Survey Expectations	0.136***	-0.292***	0.00	-	-0.263***	-
EC	Industrial New Orders SA (MoM)	-	-	-	-	0.158*	-
EC	Industrial Production SA MoM	-	-	-	-0.117*	-	-
Panel B: US News							
US	ADP Employment Change	-	-1.626***	-	-	-1.566***	-
US	Avg Weekly Hours Production	-0.242***	0.196**	0.09	-0.226***	-	-
US	Business Inventories	-0.131***	0.502***	0.01	-0.117**	0.232***	0.00
US	Change in Nonfarm Payrolls	0.144***	-0.472***	0.04	0.101**	-0.429***	*0.55*
US	Chicago Purchasing Manager	-	0.593***	-	-	0.740***	-
US	Construction Spending MoM	0.150***	0.855***	0.00	0.256***	0.589***	0.01
US	Consumer Confidence Index	0.078**	0.446***	0.00		0.624***	-
US	Core PCE QoQ - Advance	0.374***	-1.456***	0.00	0.314***	-1.143**	0.04
US	Core PCE QoQ - Preliminary	-	-2.271***	-	-	-2.335***	-
US	Durables Ex Transportation	-0.078**	-0.227***	0.03	-	-0.310***	-
US	Empire Manufacturing	0.220***	-	-	0.267***	-	-
US	Existing Home Sales	0.116**	0.934***	0.00	0.176***	0.669***	0.00
US	Factory Orders	-0.087**	-	-	-0.090**	0.154**	*0.36*
US	FOMC Rate Decision	-	0.130**	-	0.060*	-	-
US	GDP Annualized QoQ - Advance	0.284***	-	-	0.214**	-0.429***	0.01

Notes: Table 14 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on Depth at ask side and bid side with all levels in LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 14. Robustness Results of Surprise on Depth at Ask and Bid Sides (continued)

Depth		**Ask Side**			**Bid Side**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	GDP Annualized QoQ - Preliminary	0.348***	-0.906***	0.00	0.435***	-0.912***	0.03
US	Housing Starts	-0.121**	0.254***	0.00	-	0.394***	-
US	Import Price Index MoM	-	0.474***	-	0.076*	0.438***	0.04
US	Industrial Production MoM	-	0.419***	-	-	0.462***	-
US	Initial Jobless Claims	-	-0.525***	-	-	-0.599***	-
US	ISM Manufacturing	-0.098**	0.359***	0.00	-	0.434***	-
US	ISM Milwaukee	-	0.824***	-	-	1.110***	-
US	ISM Non-Manf. Composite	0.269***	-1.926***	0.00	0.394***	-2.214***	0.00
US	NAHB Housing Market Index	-	-0.286***	-	-	-0.200***	-
US	Net Long-term TIC Flows	-0.201***	-	-	-0.196***	-	-
US	New Home Sales	-0.411***	-	-	-0.509***	-	-
US	Nonfarm Productivity - Final	0.099*	-0.818***	0.09	-	-0.678***	-
US	Nonfarm Productivity - Preliminary	0.504***	0.160**	*0.78*	0.384***	0.203***	*0.98*
US	PCE Core MoM	-	-0.602***	-	-	-0.776***	-
US	Pending Home Sales MoM	0.444***	-	-	0.362***	-	-
US	Personal Consumption - Preliminary	-0.219**	-	-	-0.331***	-	-
US	Personal Spending	0.212***	0.250***	0.02	0.155**	0.369***	0.00
US	Philadelphia Fed Business Outlook	-0.084*	0.339***	0.01	-0.092*	0.363***	0.00
US	PPI Ex Food and Energy MoM	0.441***	-0.640***	0.00	0.486***	-0.684***	0.01
US	PPI MoM	-0.192***	0.950***	0.01	-0.172***	1.087***	0.00
US	Trade Balance	0.171***	-0.148*	0.01	0.211***	-0.398***	0.00
US	Unemployment Rate	-0.144***	0.415***	0.00	-0.142**	0.418***	0.01
US	Univ. of Michigan Confidence - Preliminary	-	0.235***	-	-	0.124*	-
US	Wholesale Inventories MoM	-	0.946***	-	0.084*	0.661***	0.05
US	CPI Ex Food and Energy MoM	-	-	-	-0.123***	0.489***	*0.27*

Notes: Table 14 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on Depth at ask side and bid side with all levels in LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 14. Robustness Results of Surprise on Depth at Ask and Bid Sides (continued)

Depth		**Ask Side**			**Bid Side**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel C: European Countries							
GE	IFO Business Climate	-	0.300***	-	0.122**	0.319***	*0.44*
GE	Imports QoQ	-0.150*		-	-0.167*	-	-
GE	Industrial Production SA MoM - Preliminary	-	-0.377***	-	-	-0.321***	-
GE	Private Consumption QoQ	0.217**	-	-	0.229**	-0.296**	-
GE	ZEW Survey Current Situation	-	0.304***	-	-	0.309***	-
IT	Business Confidence	-	-0.226***	-	-	-	-
IT	GDP WDA QoQ - Final	-	0.395*	-	-	-	-
IT	GDP WDA QoQ - Preliminary	-	-0.409**	-	-	-0.601***	-
IT	Total investments	-	0.784***	-	-	-	-
IT	Trade Balance Total	-0.161**	-	-	-	-	-
IT	Retail Sales MoM	-	-	-	-	-0.251***	-
SP	Unemployment Rate	-	-	-	-	-0.398**	-
FR	PPI MoM	-	0.287**	-	-	-	-
Panel D: Unscheduled News							
US	US Unscheduled News	-0.009***	0.031***	0.00	-0.008***	0.032***	0.01
EC	EC Unscheduled News	-0.015***	-0.003**	0.00	-0.017***	0.021***	0.00

Notes: Table 14 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on Depth at ask side and bid side with all levels in LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 15. Robustness Results of Surprise on Slope at Ask and Bid Sides

Slope		**Ask Side**			**Bid Side**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone News							
EC	Business Climate Indicator	0.316*	-	-	0.344**	-	-
EC	CPI Core YoY - Final	-0.349*	-	-	0.365*	-	-
EC	CPI Estimate YoY	0.654***	-	-	-	-	-
EC	Govt Expend QoQ - Preliminary	-3.195***	-	-	-5.049***	-	-
EC	Gross Fix Cap QoQ - Preliminary	-1.165*	-	-	-1.804***	-	-
EC	Household Cons QoQ - Preliminary	2.486***	-	-	3.934***	-	-
EC	Industrial New Orders SA (MoM)	-	-	-	-0.449*	-	-
EC	Industrial Production SA MoM	-	-	-	0.529*	-	-
Panel B: US News							
US	Existing Home Sales	-	1.121***	-	-	1.038***	-
US	ISM Manufacturing	0.373**	-	-	-	-	-
US	Avg Weekly Hours Production	-	-	-	-	-0.836**	-
US	Core PCE QoQ - Preliminary	-	-	-	-0.754**	-	-
US	GDP Annualized QoQ - Preliminary	-	-	-	-0.810*	-	-
US	Personal Consumption - Preliminary	-	-	-	0.825*	-	-
Panel C: European Countries News							
GE	Construction Investment QoQ	-2.065***	-	-	-	-	-
GE	Factory Orders WDA YoY - Preliminary	-	-	-	-0.269*	-	-
GE	ZEW Survey Current Situation	-	-	-	0.432**	-	-
GE	ZEW Survey Expectations	-	-	-	-0.774**	-	-
Panel D: Unscheduled News							
US	US Unscheduled News	-0.116***	0.297***	0.00	-0.123***	0.225***	0.00
EC	EC Unscheduled News	-0.193***	0.150***	0.00	-0.180***	0.112***	0.00

Notes: Table 15 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on Slope at ask side and bid side with all levels in LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 16. Robustness Results of Surprise on Volatility at different levels in the LOB

Volatility		**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone News							
EC	Govt Expend QoQ - Preliminary	-3.961*	-	-	-5.565*	-	-
EC	Labour Costs YoY	-1.472*	4.042*	0.06	-1.471**	3.579**	0.04
EC	Retail Sales MoM	-1.514*	-	-	-1.395**	-	-
EC	Gross Fix Cap QoQ - Preliminary	-	-	-	-3.402*	-	-
EC	Household Cons QoQ - Preliminary	-	-	-	4.041*	-	-
Panel B: US News							
US	ADP Employment Change	-	-2.789*	-	-	-2.776*	-
US	Change in Nonfarm Payrolls	-	-3.428***	-	-	-2.719***	-
US	Consumer Confidence Index	-0.840**	-	-	-0.859**	-	-
US	Core PCE QoQ - Advance	-	-8.217*		-	-8.387*	-
US	Empire Manufacturing	0.948*	-	-	0.955**	-	-
US	Existing Home Sales	1.255**	-	-	1.218**	-	-
US	Factory Orders	0.984**	-	-	0.967**	1.656**	0.08
US	FOMC Rate Decision	0.879***	-	-	2.506***	-	-
US	GDP Annualized QoQ - Advance	-	-3.375***	-	-	-3.274***	-
US	GDP Annualized QoQ - Preliminary	-	-3.681***	-	1.957*	-3.658**	0.07
US	Housing Starts	-0.935*	-	-	-0.975*	-	-
US	Initial Jobless Claims	-	-0.877*	-	-	-	-
US	ISM Milwaukee	-	-3.620*	-	-	-3.952**	-
US	ISM Non-Manf. Composite	1.502**	-6.169***	0.00	-	-	-
US	NAHB Housing Market Index	1.697***	-1.575**	0.00	1.749**	-1.605**	0.00
US	Nonfarm Productivity - Final	-	-3.461*	-	-	-3.608**	-
US	Nonfarm Productivity - Preliminary	1.618**	1.433**	*0.31*	1.539**	1.679**	*0.28*
US	PCE Core MoM	-	-1.990***	-	-	-1.189**	-
US	PPI Ex Food and Energy MoM	-	-1.586**	-	-	-1.338**	-
US	Trade Balance	0.771*	-	-	-	-	-
US	Industrial Production MoM	-	-	-	0.664*	-	-
US	Retail Sales Ex Auto MoM	-	-	-	-	1.152*	-

Notes: Table 16 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on volatility at 2nd to 5th level and 5th to 10th level in the LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 16. Robustness Results of Surprise on Volatility at different levels in the LOB (continued)

Volatility		**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel C: European Countries							
GE	IFO Business Climate	-	1.811**	-	-	1.758**	-
GE	Retail Sales MoM	-1.646***	-	-	-1.557**	-	-
GE	ZEW Survey Expectations	-	-4.622***	-	-	-4.702***	-
SP	CPI MoM	-	-1.289**	-	-	-1.282**	-
SP	Retail Sales WDA YoY	-	3.776**	-	-	5.056**	-
IT	Trade Balance Total	-	-2.354***	-	-	-2.317***	-
IT	Unemployment Rate Quarterly	-	-	-	-2.452*	-	-
Panel D: Unscheduled News							
US	US Unscheduled News	0.057**	-0.182***	0.00	-	-0.204***	-
EC	EC Unscheduled News	-	0.230**	-	-	0.172**	-

Notes: Table 16 presents the estimation results of news surprise effect of the significant scheduled and unscheduled macro news on volatility at 2nd to 5th level and 5th to 10th level in the LOB considered. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicates that the coefficients are statistically different over expansion and recession.

Table 17. Robustness Results of Surprise on Depth at different levels in the LOB

Depth		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone Macro News													
EC	Business Climate Indicator	-	0.624***	-	-	0.416***	-	-	-	-	-	-	-
EC	CPI Estimate YoY	-	0.432*	-	-		-	-	-	-	-	-	-
EC	GDP SA QoQ - Final	-	-0.424*	-	-	-0.439*	-	-	-	-	-	-	-
EC	Gross Fix Cap QoQ Preliminary	0.656**	-0.702**	*0.16*	0.993***	-	-	-	-	-	1.218***	-	-
EC	Industrial New Orders SA (MoM)	-	0.432***	-	-	0.28*	-	-	-	-	-	0.295*	-
EC	Labour Costs YoY	-	-0.893**	-	-	-	-	-	-	-	-	-	-
EC	Trade Balance SA	-	0.42***	-	-	0.501***	-	-	-	-	-	-	-
EC	CPI Core YoY - Final	-	-	-	-	-0.251*	-	-0.196**	-	-	-	-	-
EC	Gross Fix Cap QoQ - Final	-	-	-	-0.815***	-	-	-	-	-	-	-	-
EC	Household Cons QoQ Preliminary	-	-	-	-0.826**	-	-	-	-	-	-0.959**	-	-
EC	Industrial Production SA MoM	-	-	-	-0.243**	-	-	-	-	-	-	-	-
EC	Govt Expend QoQ - Preliminary	-	-	-	-	-	-	-	-	-	1.104**	-	-
EC	PMI Manufacturing - Preliminary	-	-	-	-	-	-	-	-	-	0.247**	-	-
EC	Retail Sales MoM	-	-	-	-	-	-	-	-	-	-	-0.241*	-
EC	ZEW Survey Expectations	-	-	-	-	-	-	-	-	-	-	0.282*	-

Notes: Table 17 presents estimation results of the news surprise effect and unscheduled news effect on depth at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 17. Robustness Results of Surprise on Depth at different levels in the LOB (continued)

Depth		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel B: US News													
US	ADP Employment Change	-	-0.550**	-	-	-1.250***	-	-0.196**	-1.435***	-	-	-1.434***	
US	Avg Weekly Hours Production	-0.205**	-	-	-	-	-	-	-	-	-0.176***	-0.289*	*0.29*
US	Business Inventories	-	0.312**	-	-	0.413***	-	-0.306***	0.724***	-	-	0.482***	
US	Change in Nonfarm Payrolls	0.169*	-0.561***	0.03	-	-0.739***	-	-	-0.512**	-	-	-0.590***	
US	Chicago Purchasing Manager	-	0.492***	-	-	0.603***	-	-	0.547***	-	-	0.775***	
US	Construction Spending MoM	0.151*	0.365*	0.00	0.173*	0.544***	0.01	-		-	0.282***	0.522***	0.00
US	Consumer Confidence Index	-	0.920***	-	-	0.365**	-	-	1.054***	-	-	-	-
US	Core PCE QoQ - Advance	-	-1.922**	-	-	-2.111**	-	-	-1.816**	-	-	-	-
US	Core PCE QoQ - Preliminary	-0.360**	-0.689*	*0.94*	-	-1.427***	-	-0.408**	-	-	-	-1.096***	-
US	Durables Ex Transportation	-	-0.448***	-	-	-	-	-	-	-	-	-0.232*	-
US	Empire Manufacturing	-	0.473***	-	-	0.532***	-	-	0.418***	-	-	0.516***	-
US	Existing Home Sales	-	0.356**	-	-	0.414***	-	-0.178**	-0.495***	0.00	0.211**	-	-
US	GDP Annualized QoQ - Advance	-	-0.897***	-	-	-	-	-	-0.927***	-	-	-0.848***	-
US	GDP Annualized QoQ Preliminary	-	-0.897***	-	-	-1.011***	-	-	-0.649*	-	-	-1.201***	-
US	Housing Starts	-	0.735***	-	-	0.382***	-	-0.170*	0.586***	0.00	-	0.602***	-

Notes: Table 17 presents estimation results of the news surprise effect and unscheduled news effect on depth at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 17. Robustness Results of Surprise on Depth at different levels in the LOB (continued)

Depth		Ask Side						Bid Side					
		2nd to 5th level			5th to 10th level			2nd to 5th level			5th to 10th level		
CN	Scheduled News	Recession	Expansion	P-diff	Recession	Expansion	P-diff	Recession	Expansion	P-diff	Recession	Expansion	P-diff
US	IBD/TIPP Economic Optimism	-	-0.441**	-	-	-	-	-	-	-	-	-	-
US	Initial Jobless Claims	-	-0.205**	-	-	-0.403***	-	-	-0.308***	-	-	-0.446***	-
US	ISM Milwaukee	0.619***	-1.079***	0.00	0.413**	-	-	-	-	-	-	0.989***	-
US	New Home Sales	-0.477**	0.382***	0.00	-0.762***	0.523***	0.00	-0.506***	0.410***	0.02	-0.661***	0.485***	0.00
US	Nonfarm Productivity - Final	-	0.651**	-	-	-	-	-	-	-	-	-0.722**	-
US	Nonfarm Productivity - Preliminary	0.549***	-	-	0.524***	-	-	0.402**	-	-	0.387***		-
US	PCE Core MoM	-	-0.349***	-	-	-0.388***	-	-	-0.334**	-	-	-0.244**	-
US	Pending Home Sales MoM	-	-0.842***	-	-	-0.370**	-	0.285**	-0.856***	0.03	0.273**	-0.331**	0.00
US	Personal Spending	-	0.466***	-	0.357***	0.236*	0.01	-	0.332*	-	-	-	-
US	Philadelphia Fed Business Outlook	-	-0.318**	-	-	0.381**	-	-	-0.498***	-	-	-	-
US	PPI Ex Food and Energy MoM	0.214*	-0.394***	0.00	0.301**	-0.352***	0.02	-	0.521**	-	0.274**	-0.322***	0.00
US	PPI MoM	-0.189*	0.507***	0.04	-0.212*	0.567***	0.01	-	-0.272*	-	-	0.42**	-
US	Retail Sales Ex Auto MoM	-	-0.233*	-	-	-	-	-0.229**	-	-	-	-	-
US	Unemployment Rate	-0.250**	-	-	-	-	-	-	0.258*	-	-	-	-
US	Univ. of Michigan Confidence - Preliminary	-	0.244**	-	-	-	-	-	1.093*	-	-	-	-
US	Wholesale Inventories MoM	-	1.465***	-	-	0.675***	-	-	0.332***	-	-	0.859**	-
US	Personal Consumption - Preliminary	-	-	-	-	-	-	0.424**	-	-	-	-	-

Notes: Table 17 presents estimation results of the news surprise effect and unscheduled news effect on depth at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 17. Robustness Results of Surprise on Depth at different levels in the LOB (continued)

Depth		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Factory Orders	-	-	-	-	-0.264**	-	-	-	-	-	-	-
US	ISM Manufacturing	-	-	-	-	-	-	-	0.284*	-	-	0.242*	-
US	NAHB Housing Market Index	-	-	-	-	-0.266**	-	0.247*	-	-	-	-	-
US	Pending Home Sales MoM	-	-	-	-	-	-	-	-	-	-	-	-
US	Import Price Index MoM	-	-	-	-	0.866***	-	-	-	-	-	-	-
US	Industrial Production MoM	-	-	-	-	-0.644***	-	-	-	-	-	-	-
US	Trade Balance	-	-	-	-	0.46***	-	-	-	-	-	-	-
US	CPI Ex Food and Energy MoM	-	-	-	-	-	-	-	-	-	-	0.444**	-
US	ISM Non-Manf. Composite	-	-	-	-	-	-	-	-	-	0.351***	-0.449*	0.00
Panel C: European Countries													
GE	Factory Orders WDA YoY - Preliminary	-	0.237**	-	-	-	-	-	-	-	-	-0.209**	-
GE	Industrial Production SA MoM - Preliminary	-	-0.424***	-	-0.129*	-	-	-	-0.6***	-	-	-0.27*	-
GE	Private Consumption QoQ	0.360*	-	-	1.029***	-0.666**	*0.23*	-	-	-	-	-0.455*	-
GE	ZEW Survey Current Situation	0.167*	-	-	-	0.506**	-	0.31***	-	-	0.204**	-	-
GE	ZEW Survey Expectations	-	-1.267***	-	-	-0.776***	-	-	-0.715***	-	-	-1.263***	-
GE	IFO Business Climate	-	-	-	-	0.248*	-	0.212*	-	-	0.193**	0.301**	0.02

Notes: Table 17 presents estimation results of the news surprise effect and unscheduled news effect on depth at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 17. Robustness Results of Surprise on Depth at different levels in the LOB (continued)

Depth		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
GE	Construction Investment QoQ	-	-	-	1.108**	-	-	-	-	-	-	-	-
GE	Exports QoQ	-	-	-	0.44**	1.348*	*0.39*	-	-	-	-	-	-
GE	Imports QoQ	-	-	-	-0.641***	-	-	-	-	-	-	-	-
GE	Unemployment Rate	-	-	-	-	-	-	-	-	-	0.139*	-	-
PO	CPI MoM	-	0.418*	-	-	-	-	-	-	-	-	-	-
PO	GDP YoY - Final	-	-	-	-	-	-	-	-	-	-0.369*	-	-
IT	GDP WDA QoQ - Preliminary	-	-0.878**	-	-	-	-	-	-	-	-	-	-
IT	Industrial Production WDA YoY	-	-	-	0.184*	-	-	-	-	-	0.192**	-0.296*	*0.53*
IT	Retail Sales MoM	-	-	-	-	-0.34**	-	-	-	-	-	-0.419**	-
IT	Trade Balance Total	-	-	-	-	-	-	-	-	-	-	0.337**	-
FR	Own-Company Production Outlook	-	0.459**	-	-	-	-	-	-	-	-	-	-
FR	Consumer Spending (MoM)	-	-	-	0.229*	-	-	-	-	-	-	-	-
SP	Retail Sales WDA YoY	-	-	-	-	-	-	0.298*	-	-	-	-0.622*	-
SP	CPI MoM	-	-	-	-	0.19*	-	-	-	-	-	-	-
SP	Unemployment Rate	-	-	-	-	0.764*	-	-	-	-	-0.551***	-	-
US	US Unscheduled News	-	-0.140***	-	-0.040***	-	-	-0.070***	-	-	-0.021***	-0.043***	0.00
EC	EC Unscheduled News	-0.033**	0.023***	0.00	-0.052***	0.076***	-	-0.066***	0.032**	0.00	-0.047***	-	-

Notes: Table 17 presents estimation results of the news surprise effect and unscheduled news effect on depth at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 18. Robustness Results of Surprise on Slope at different levels in the LOB

Slope		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
Panel A: Euro Zone News													
EC	Gross Fix Cap QoQ - Preliminary	0.715*	-	-	-	-	-	1.215***	-	-	-	-	-
EC	Household Cons QoQ - Preliminary	-0.801*	0.498*	*0.34*	-	-	-	-1.049*	-	-	-0.746*	-	-
EC	GDP SA QoQ - Final	-	-	-	-	-	-	-0.628***	-	-	0.290*	-	-
EC	Govt Expend QoQ - Preliminary	-	-	-	-	-	-	0.933*	-	-	-	-	-
EC	PMI Manufacturing - Preliminary	-	-	-	-	-	-	0.248*	-	-	-0.176*	-	-
EC	Trade Balance SA	-	-	-	0.31**	-	-	-	0.514**		0.18**	-	-
EC	Labour Costs YoY	-	-	-	0.551*	-	-	-	-	-	-	-	-
EC	ZEW Survey Expectations	-	-	-	-0.344**	-	-	-	-	-	-	-0.316**	-
EC	CPI Estimate YoY	-	-	-	-	-	-	-	-	-	-	-0.521**	-
EC	Industrial Production SA MoM	-	-	-	-	-	-	-	-	-	-	-0.337*	-
Panel B: US News													
US	ADP Employment Change	-	-0.735*	-	-	-1.324***					0.159**	-0.962***	*0.7*
US	Avg Weekly Hours Production	-0.259**	-	-	-0.318**	-	-	-0.259**	-	-	-0.316***	-	-
US	Chicago Purchasing Manager	0.231*	-	-	-	0.331**	-	-	-	-	-	0.339**	-
US	Construction Spending MoM	0.255**	-	-	0.349**	0.378*	0.02	-	-	-	0.265***	-	-
US	Consumer Confidence Index	-0.258**	-	-	-	-	-	-	-	-	-	-	-

Notes: Table 18 presents estimation results of the news surprise effect and unscheduled news effect on slope at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 18. Robustness Results of Surprise on Slope at different levels in the LOB (continued)

Slope		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Core PCE QoQ – Preliminary	0.371*	-0.997**	*0.49*	-	-0.963***	-	-	-1.749***	-	0.445***	-1.747***	0.02
US	Durables Ex Transportation	0.211**	-	-	-	-	-	-	-	-	-	-	-
US	Existing Home Sales	-	0.594***	-	-	-	-	-	-	-	-	0.414***	-
US	FOMC Rate Decision	-0.144*	-	-	-	-	-	-	-	-	-	-	-
US	GDP Annualized QoQ - Preliminary	0.644**	-	-	0.576**	-	-	-	-	-	0.955***	-0.971***	0.06
US	Initial Jobless Claims	-	-0.213*	-	-	-0.287***	-	-	-0.319***	-	-	-0.275***	-
US	ISM Milwaukee	-	0.825*	-	-0.341*	1.171***	0.05	-	-	-	-	1.253***	-
US	ISM Non-Manf. Composite	-	-0.979*	-	-	-1.481***	-	-	-2.273***	-	-	-0.956***	-
US	New Home Sales	-	0.398**	-	-	-0.267**	-	-	-	-	-	-	-
US	Nonfarm Productivity - Preliminary	0.535***	-	-	-	0.443***	-	0.333*	-	-	0.503***	0.338***	*0.18*
US	PCE Core MoM	-	-0.550***	-	-	-0.218*	-	-	-	-	0.208*	-0.392***	0.1
US	Personal Consumption - Preliminary	-0.528*	-	-	-0.564**	-	-	-	-	-	-0.903***	-	-
US	Personal Spending	-	0.39*	-	-	0.246*	-	-	0.479**	-	-	0.346**	-
US	PPI Ex Food and Energy MoM	0.424*	-0.628***	0.00	0.33***	-0.312*	0.01	-	-	-	-	-	-
US	PPI MoM	-	0.82***	-	-	-	-	0.263*	-	-	0.372***	0.52***	0.15
US	Trade Balance	0.205**	-	-	0.258**	-	-	-	-	-	0.266***	-	-
US	Unemployment Rate	-	0.61**	-	-	-	-	-	0.759*	-	-	-	-

Notes: Table 18 presents estimation results of the news surprise effect and unscheduled news effect on slope at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

Table 18. Robustness Results of Surprise on Slope at different levels in the LOB (continued)

Slope		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
US	Import Price Index MoM	-	-	-	-	0.274*	-	0.217**	-	-	0.261***	-	-
US	Net Long-term TIC Flows	-	-	-	-0.204**	0.27*	0.07	-0.314**	0.485**	0.02	-0.176*	0.271*	0.03
US	Business Inventories	-	-	-	-0.167*	0.327**	*0.28*	-	-	-	-0.165*	-	-
US	Change in Nonfarm Payrolls	-	-	-	0.29***	-	-	0.239*	-0.467**	0.05	0.173*	-	-
US	Housing Starts	-	-	-	-	0.267**	-	-	-	-	-	-	-
US	IBD/TIPP Economic Optimism	-	-	-	-	0.419**	-	-	-	-	-	-	-
US	ISM Manufacturing	-	-	-	0.232**	0.292**	0.00	-	-	-	-	-	-
US	Nonfarm Productivity – Final	-	-	-	-	-0.718**	-	-	-	-	0.218**	-	-
US	Pending Home Sales MoM	-	-	-	0.256**	-	-	-	-0.494*	-	0.324***	0.358**	0.03
US	Philadelphia Fed Business Outlook	-	-	-	-0.166**	-	-	-	-	-	-0.154*	0.264*	*0.27*
US	Retail Sales Ex Auto MoM	-	-	-	-	-	-	-	-	-	0.175**	-	-
US	Univ. of Michigan Confidence - Preliminary	-	-	-	-	-	-	-0.262**	-	-	-	0.368***	-
Panel C: European Countries News													
GE	Imports QoQ	-	0.735*	-	-	-	-	-	0.735*	-	-	-	-
GE	Industrial Production SA MoM - Preliminary	-	0.529**	-	-	0.274*	-	-	0.529**	-	-	-	-
GE	Retail Sales MoM	-	-1.57***	-	-	-	-	-0.224***	-	-	-0.17*	-0.235**	*0.25*
GE	GDP SA QoQ - Preliminary	-	-	-	0.196*	-	-	-	-	-	-	-	-

Notes: Table 18 presents estimation results of the news surprise effect and unscheduled news effect on slope at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

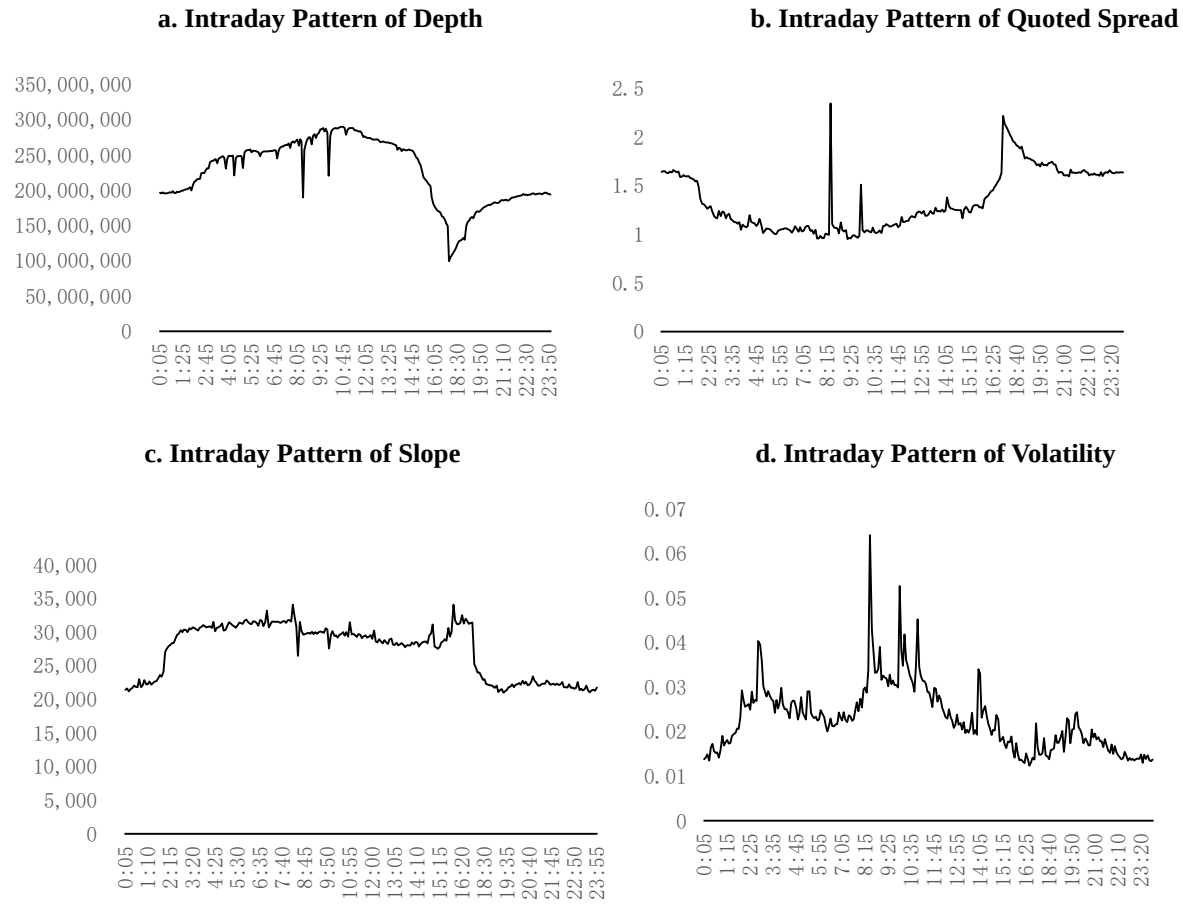
Table 18. Robustness Results of Surprise on Slope at different levels in the LOB (continued)

Slope		**Ask Side**						**Bid Side**					
		2nd to 5th level			**5th to 10th level**			**2nd to 5th level**			**5th to 10th level**		
CN	**Scheduled News**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**	**Recession**	**Expansion**	**P-diff**
GE	PPI MoM	-	-	-	-0.125*	-	-	-	-	-	-	-	-
SP	Retail Sales WDA YoY	-	1.57***	-	-	-	-	-	-	-	-	-	-
SP	Unemployment Rate	-0.484**	-	-	-	-	-	-	-	-	-	-	-
SP	CPI MoM	-	-	-	0.172*	-	-	-	-	-	-	-	-
IT	Industrial Production WDA YoY	-	-0.408*	-	-	-	-	-	-	-	-	-	-
IT	Retail Sales MoM	-	-	-	0.308***	-	-	0.365***	-	-	0.195*	-0.487***	0.01
FR	PPI MoM	-0.172**	-	-	-	-	-	-	-	-	-	-	-
FR	Consumer Spending (MoM)	-	-	-	-	-	-	-	-	-	-0.215*	-	-
Panel D: Unscheduled News													
US	US Unscheduled News	0.014***	0.146***	0.00	-0.007**	0.091***	0.01	-	0.103***	-	0.017***	0.039***	0.00
EC	EC Unscheduled News	-0.056***	0.051***	0.00	-0.02***	-	-	-0.030***	0.098***	0.02	-0.023***	0.039***	0.00

Notes: Table 18 presents estimation results of the news surprise effect and unscheduled news effect on slope at 2nd to 5th levels and 5th to 10th levels in the LOB at ask side and bid side. CN presents the corresponding country name of the news: EC - Euro Zone; GE - German; US – United States; FR - France; IT - Italy; PO - Poland; SP - Spain. *, **, *** denotes the prob. of insignificance of news are at 1%, 5% and 10% levels respectively. P_diff presents the difference between the coefficients in expansion and recession. A significant value of P_diff indicate that the coefficients are statistically different over expansion and recession.

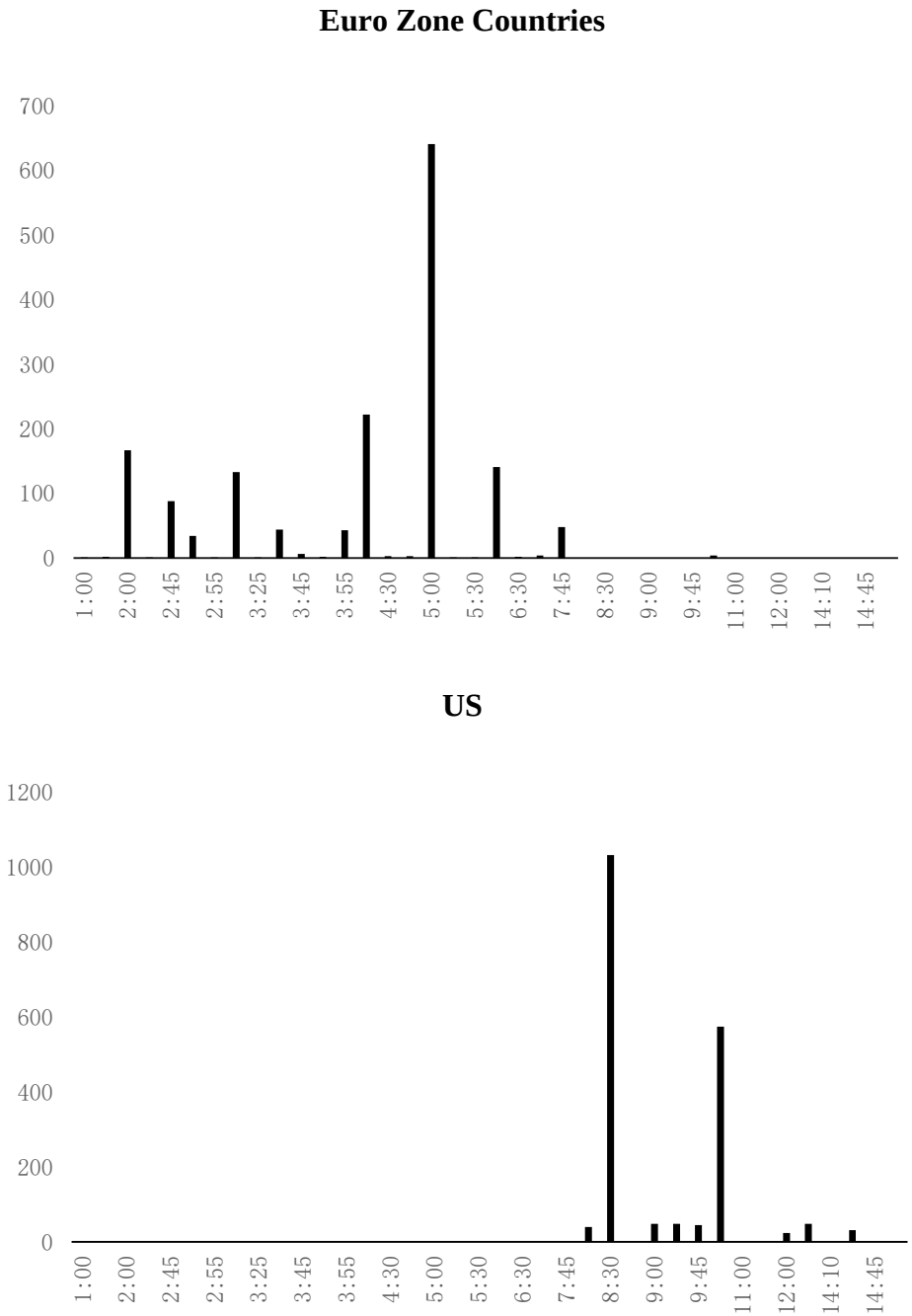
Figures

Figure 1. Intraday Pattern of Characteristics



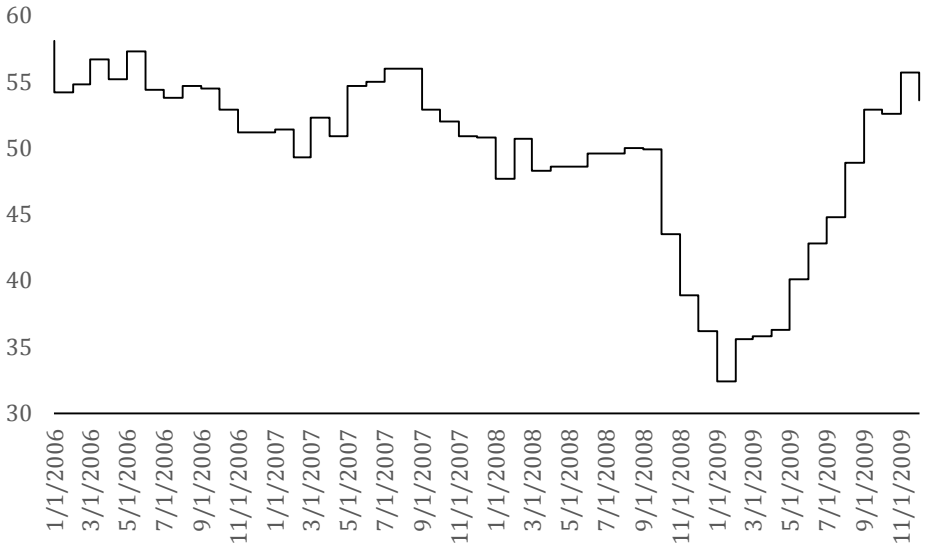
Notes: Figure 1 presents the intraday patterns of depth, quote spread, slope and volatility from Jan 3, 2006 to Dec 31, 2009. For each graph, the x-axis is the 275 intervals in a trading day, and the title displays the name of the variable depicted. Un-weighted averages across all intervals in one day are shown. All variables are drawn without adjustment for intraday seasonality.

Figure 2. Intraday Announcement Cluster



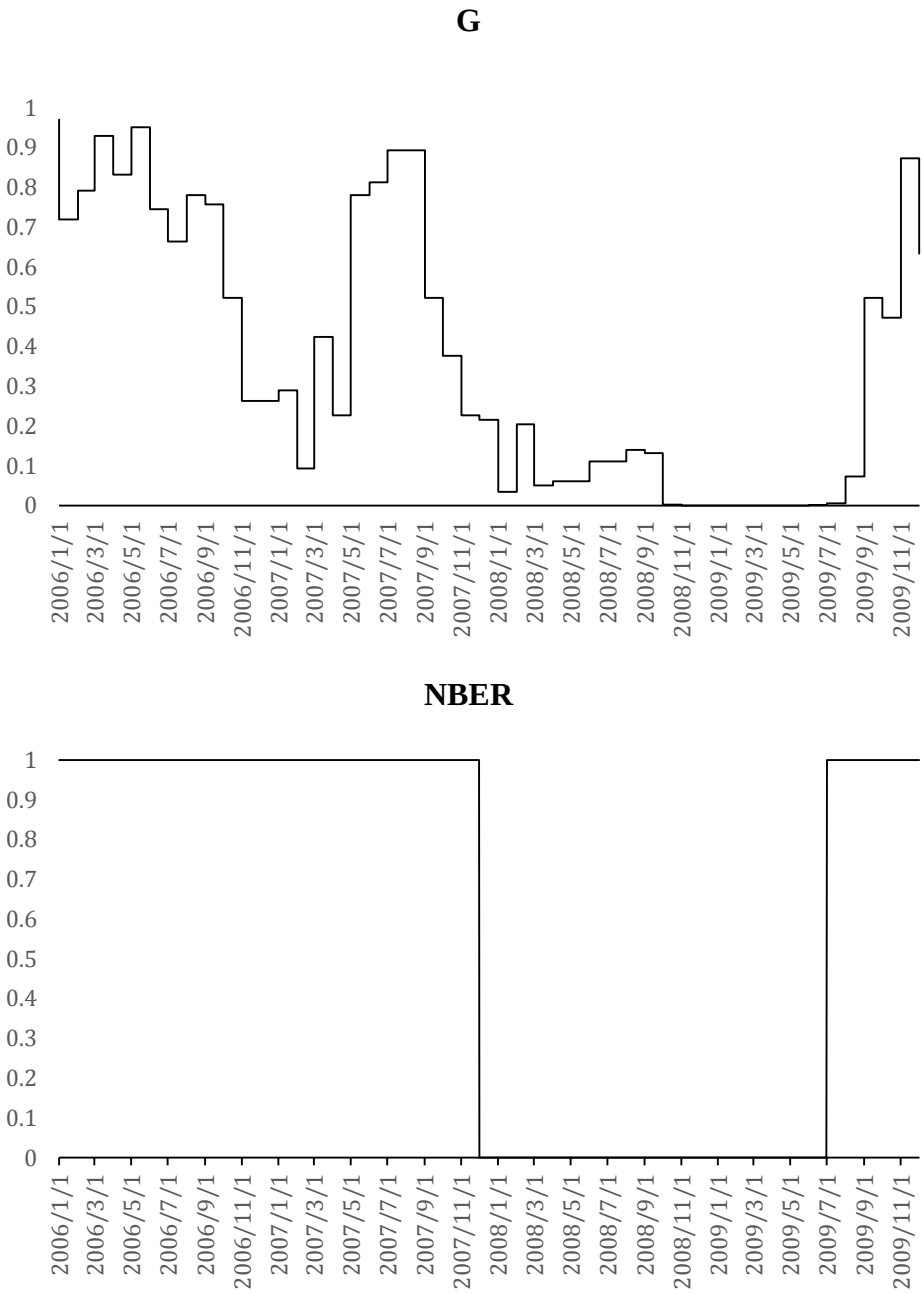
Notes: Figure 2 plots the bar charts for the cumulated macroeconomic news announcements frequencies from Jan 3, 2006 to Dec 31, 2009. The news included here are the total number of valid news filtered by the first round of filtered introduced in section 4.1.3. The Vertical Axis is the number of announcements. The Horizontal Axis is the time a news announced stamped to minutes.

Figure 3. Transition Variable ISM



Notes: Figure 3 plots regime indicator, ISM from 2006 to 2009. ISM (Institute of Supply Management) is manufacturing index for US business cycles. The value of 50 means that half of the survey participants believe the economy is in good state and half think it is bad state. ISM below 50 indicates worse economy condition. The Vertical Axis is the magnitude of ISM.

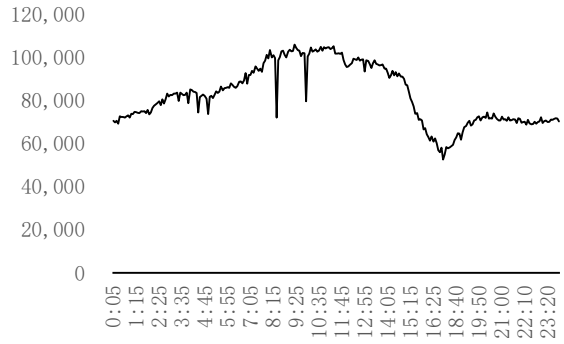
Figure 4. Estimation Results of Logistic Transition Function



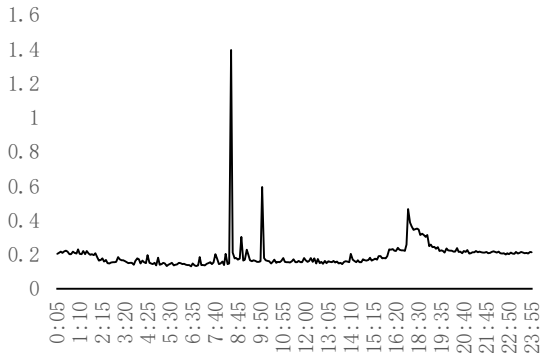
Notes: Figure 4 plots the fitted G from (1) and NBER dates from 2006 to 2009. G is between 0 (lower regime: recession) and 1 (higher regime: expansion). NBER is 1 when economy is in expansion; NBER is 0 which indicates economy is in recession.

Figure 5. Intraday Patterns of Alternative Characteristics

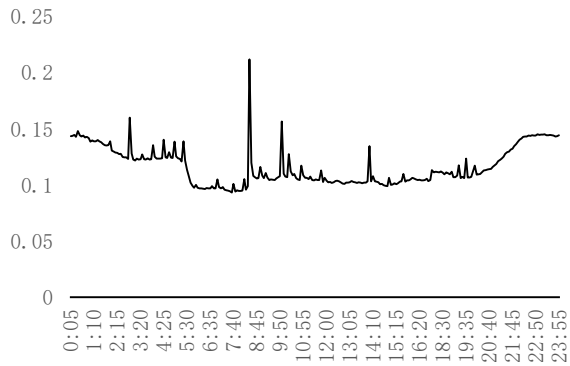
a. Intraday Pattern of NORMSLOPE



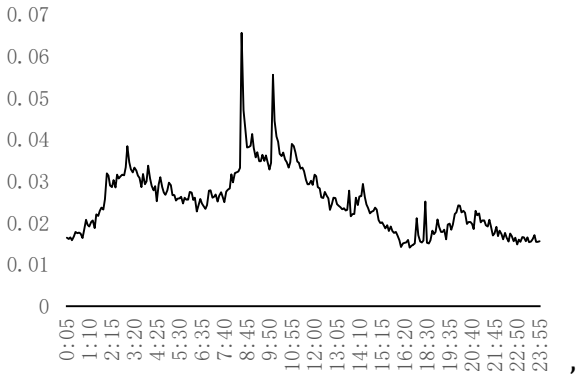
b. Intraday Pattern of WSLOPE



c. Intraday Pattern of SIZESPREAD



d. Intraday Pattern of Volatility



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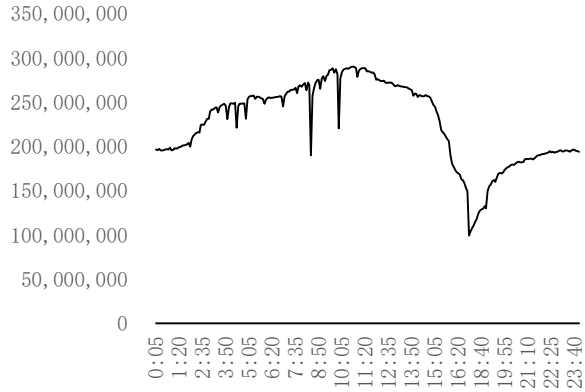
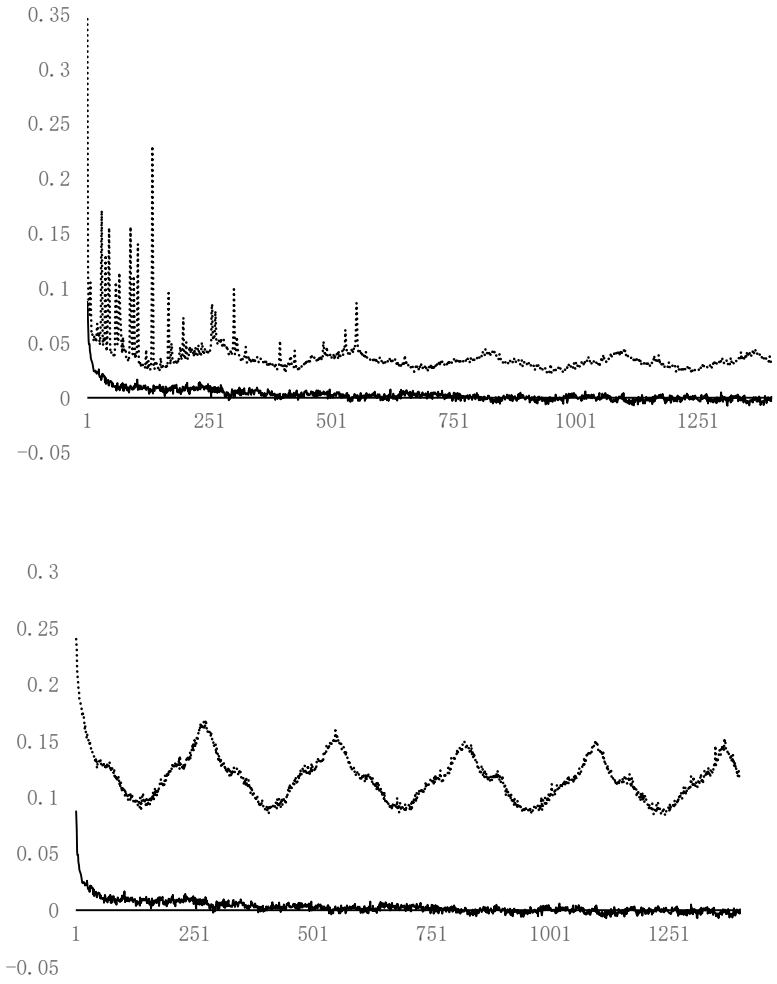
e. Intraday Pattern of SIZE



Notes: Figure 5 presents the intraday patterns of alternative measures of slope (NORMSLOPE and WSLOPE), depth (SIZE) and spread (SIZESPREAD) from 2006 to 2009. In each graph, the x-axis the 5-min interval trading periods of a trading day, while the title displays the name of the variable depicted. Un-weighted averages across all intervals in one day are shown. All variables are not adjusted for intraday seasonality.

Figure 6. Autocorrelation Coefficients of Log Transformed Filtered Volatility



Notes: Figure 6 shows the correlogram of autocorrelation coefficients of two method of volatility with total lag 1400 intervals which contains five days of since each day contain 275 intervals. The dashed line in the above figure shows the correlogram of 5-min absolute returns, *Abs_return* and its corresponding log-transformed filtered volatility, Volat. The dashed line in the below figure shows the correlogram of 5-min absolute returns, *Abs_ret*, and its corresponding log-transformed filtered volatility, Y. Vertical axis shows the magnitude of autocorrelation coefficients.

Appendix A

In the Appendix A, we give an example of VAR-STR model for alternative measures of characteristics. For the category "slope", we have three measures of "slope", which are introduced in section 3; "NORM SLOPE" is calculated with the same logic of "slope" except that the "NORM SLOPE" for a tick is normalized with regard of the total size on that tick. The third slope measures is size-weighted slope by Kozhan and Salmon (2010). For the category "spread", we have two measures of "spread": "quoted spread" introduced in section 3 and size-weighted spread. Also, we have two measures of "volatility" with respect to two measures of return. One is return is calculated by size-weighted price introduced in section 3, the other is the return calculate by price.

For example, in the case of "NORM SLOPE", volatility based on the best quote (6.1.4), the size (6.1.1) and the size-weighted spread, the VAR-STR model with exogenous variables news surprise S_q is:

$$\Omega_{t,n} = \alpha_{t,n} + \sum_j^J \beta_j \Omega_{t,n-j} + \lambda AV_{t,n} + \sum_{q=1}^Q \theta_q \mathrm{S}_{q,t,n} + \eta_1 unsch_{t,n}^{US} + \eta_2 unsch_{t,n}^{EC} + \left\{\alpha'_{t,n} + \sum_{q=1}^Q \theta'_q \mathrm{S}_{q,t,n} + \eta'_1 unsch_{t,n}^{US} + \eta'_2 unsch_{t,n}^{EC}\right\}\hat{G}\left(\psi_{t,n}, \gamma, c\right) + \varepsilon_{t,n} \qquad (14)$$

Similar as the case of equation (8), the vector of endogenous variable in (13) is: $\Omega_{t,n} = \left(Depth_{t,n}, Slope_{t,n}^{NORM}, WSPREAD_{t,n}, Volat_{t,n}\right)'$, where $WSPREAD_{t,n}$ is the size-weighted spread at interval *n* on day *t*; $Slope_{t,n}^{NORM}$ is the NORM SLOPE at interval *n* on day *t*; And $AV_{t,n}$ is the seasonality dummy of quoted depth, WSPREAD and NORM SLOPE are $AV_{t,n}^{depth}$, $AV_{t,n}^{wspread}$ or $AV_{t,n}^{normslope}$ respectively.

Appendix B

Appendix B shows the additional data for equation (7) and (11).

1. Daily Exchange Rate

In the section 3.4.2, the daily spot exchange rate return data was needed beyond our sample range to construct one day ahead volatility component in FFF equation. The sample of daily spot exchange rates was from the initial year of the euro by using Bloomberg HP (Historical Price) function.

2. Consolidated Macroeconomic news variable

Consolidated Macroeconomic News vector is used to obtain the fitted transaction variable in equation (2). Before the polynomial structure, regardless of country and category, we construct a dummy which equals one as long as news occurs, otherwise the dummy is zero. Then we construct a third order polynomial structure to create a vector that can capture the decay impact on volatility within two hours (Andersen et al., 2003):

$$\rho(n) = c_0\left(1-\left(\frac{n}{I}\right)^3\right)+c_1\left(1-\left(\frac{n}{I}\right)^2\right)n + c_2\left(1-\frac{n}{I}\right)n^2, \quad (15)$$

where response window n=1….25 is the number of interval. And n=25 is the sum intervals of two hours (5-min interval). $\rho(n)$ describes the decay pattern for the effect of news on volatility. $\rho(n)$ is the fitted values corresponding to the difference between the average absolute return at each time interval just after the news announcements and the average absolute return computed for the whole sample .

Appendix C

Name list of news and country is shown in the Appendix C. Advance/Preliminary/Final denotes Advance, Preliminary and Final report for a certain news that announced for several time with revision of the figures. Effect describe the standard to classify the news in to good or bad. SA/NSA means Seasonal Adjusted or Non Seasonal Adjusted figures. YoY, MoM, QoQ denotes the comparison between the current released figure and the previous figure Year over Year, Month over Month, Quarter over Quarter. WDA denotes for Weighted Density Approximation.[15]

Country	News	Effect
EC	Business Climate Indicator	Actual > Forecast = Good News
EC	CPI Core YoY -Final	Actual > Forecast = Good News
EC	CPI Estimate YoY	Actual > Forecast = Good News
EC	ECB Announces Interest Rates	Actual > Forecast = Good News
EC	GDP SA QoQ -Final	Actual > Forecast = Good News
EC	Govt Expend QoQ -Preliminary	Actual > Forecast = Good News
EC	Gross Fix Cap QoQ -Final	Actual > Forecast = Good News
EC	Gross Fix Cap QoQ -Preliminary	Actual > Forecast = Good News
EC	Household Cons QoQ -Preliminary	Actual > Forecast = Good News
EC	Industrial New Orders SA (MoM)	Actual > Forecast = Good News
EC	Industrial Production SA MoM	Actual > Forecast = Good News
EC	Labour Costs YoY	Actual > Forecast = Good News
EC	PMI Manufacturing -Preliminary	Actual > Forecast = Good News
EC	Retail Sales MoM	Actual > Forecast = Good News
EC	Trade Balance SA	Actual > Forecast = Good News
EC	ZEW Survey Expectations	Actual > Forecast = Good News
US	ADP Employment Change	Actual > Forecast = Good News
US	Avg Hourly Earning MOM Prod	Actual > Forecast = Good News
US	Avg Weekly Hours Production	Actual > Forecast = Good News

[15] The source are Bloomberg and www.Forexfactory.com

US	Business Inventories	Actual < Forecast = Good News
US	Change in Nonfarm Payrolls	Actual > Forecast = Good News
US	Chicago Purchasing Manager	Actual > Forecast = Good News
US	Construction Spending MoM	Actual > Forecast = Good News
US	Consumer Confidence Index	Actual > Forecast = Good News
US	Core PCE QoQ -Advance	Actual > Forecast = Good News
US	Core PCE QoQ -Preliminary	Actual > Forecast = Good News
US	CPI Ex Food and Energy MoM	Actual > Forecast = Good News
US	Durables Ex Transportation	Actual > Forecast = Good News
US	FOMC Rate Decision	Actual > Forecast = Good News
US	Empire Manufacturing	Actual > Forecast = Good News
US	Factory Orders	Actual > Forecast = Good News
US	Existing Home Sales	Actual > Forecast = Good News
US	GDP Annualized QoQ -Advance	Actual > Forecast = Good News
US	GDP Annualized QoQ -Preliminary	Actual > Forecast = Good News
US	Housing Starts	Actual > Forecast = Good News
US	IBD/TIPP Economic Optimism	Actual > Forecast = Good News
US	Import Price Index MoM	Actual > Forecast = Good News
US	Industrial Production MoM	Actual > Forecast = Good News
US	Initial Jobless Claims	Actual < Forecast = Good News
US	ISM Manufacturing	Actual > Forecast = Good News
US	ISM Milwaukee	Actual > Forecast = Good News
US	ISM Non-Manf. Composite	Actual > Forecast = Good News
US	Net Long-term TIC Flows	Actual > Forecast = Good News
US	NAHB Housing Market Index	Actual > Forecast = Good News
US	New Home Sales	Actual > Forecast = Good News
US	Nonfarm Productivity -Final	Actual > Forecast = Good News
US	Nonfarm Productivity -Preliminary	Actual > Forecast = Good News

US	PCE Core MoM	Actual > Forecast = Good News
US	Pending Home Sales MoM	Actual > Forecast = Good News
US	Personal Consumption -Preliminary	Actual > Forecast = Good News
US	Personal Spending	Actual > Forecast = Good News
US	Philadelphia Fed Business Outlook	Actual > Forecast = Good News
US	PPI Ex Food and Energy MoM	Actual > Forecast = Good News
US	PPI MoM	Actual > Forecast = Good News
US	Retail Sales Ex Auto MoM	Actual > Forecast = Good News
US	Trade Balance	Actual > Forecast = Good News
US	Unemployment Rate	Actual < Forecast = Good News
US	Univ. of Michigan Confidence -Preliminary	Actual > Forecast = Good News
US	Wholesale Inventories MoM	Actual < Forecast = Good News
SP	CPI EU Harmonised YoY -Final	Actual > Forecast = Good News
SP	CPI MoM	Actual > Forecast = Good News
SP	Retail Sales WDA YoY	Actual > Forecast = Good News
SP	Unemployment Rate	Actual < Forecast = Good News
PO	CPI MoM	Actual > Forecast = Good News
PO	GDP YoY -Final	Actual > Forecast = Good News
IT	Business Confidence	Actual > Forecast = Good News
IT	GDP WDA QoQ -Final	Actual > Forecast = Good News
IT	Industrial Production WDA YoY	Actual > Forecast = Good News
IT	Retail Sales MoM	Actual > Forecast = Good News
IT	Total investments	Actual > Forecast = Good News
IT	Trade Balance Total	Actual > Forecast = Good News
IT	Unemployment Rate Quarterly	Actual < Forecast = Good News
GE	Construction Investment QoQ	Actual > Forecast = Good News
GE	Exports QoQ	Actual > Forecast = Good News

GE	Factory Orders WDA YoY -Preliminary	Actual > Forecast = Good News
GE	GDP SA QoQ -Preliminary	Actual > Forecast = Good News
GE	IFO Business Climate	Actual > Forecast = Good News
GE	Imports QoQ	Actual > Forecast = Good News
GE	Industrial Production SA MoM -Preliminary	Actual > Forecast = Good News
GE	PPI MoM	Actual > Forecast = Good News
GE	Private Consumption QoQ	Actual > Forecast = Good News
GE	Retail Sales MoM	Actual > Forecast = Good News
GE	Unemployment Rate	Actual < Forecast = Good News
GE	ZEW Survey Current Situation	Actual > Forecast = Good News
GE	ZEW Survey Expectations	Actual > Forecast = Good News
FR	Consumer Spending (MoM)	Actual > Forecast = Good News
FR	Own-Company Production Outlook	Actual > Forecast = Good News
FR	PPI MoM	Actual > Forecast = Good News

Appendix D

Appendix D shows the diagram of LOB.

Diagram 1